This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

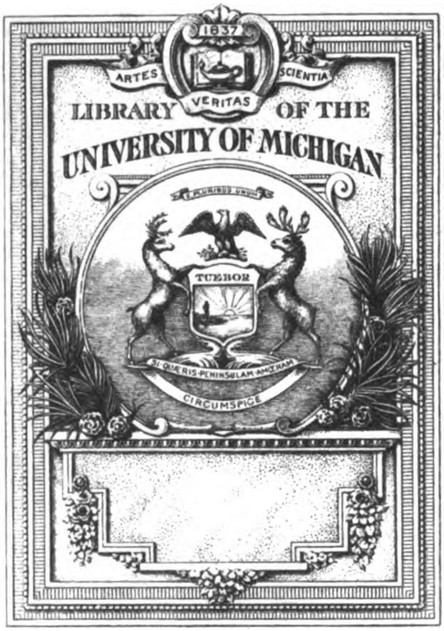
+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`


1837
ARTES
VERITAS
SCIENTIA
LIBRARY OF THE
UNIVERSITY OF MICHIGAN
E PLURIBUS UNUM
TUEBOR
SI QUÆRIS PENINSULAM AMŒNAM
CIRCUMSPICE

THE JOURNAL
OF
COMPARATIVE PSYCHOLOGY

EDITED BY
KNIGHT DUNLAP
Johns Hopkins University
AND
ROBERT M. YERKES
National Research Council

VOLUME II

BALTIMORE, MD.
1922

M1
I
[illegible]
v. 2

MAR 29 1922

VOLUME II FEBRUARY, 1922 NUMBER 1

THE JOURNAL OF COMPARATIVE PSYCHOLOGY

Continuing Psychobiology and the
Journal of Animal Behavior

EDITED BY

KNIGHT DUNLAP
Johns Hopkins University

AND

ROBERT M. YERKES
National Research Council

IN ASSOCIATION WITH

MADISON BENTLEY
University of Illinois

HARVEY CARR
University of Chicago

WALTER B. CANNON
Harvard University

RAYMOND DODGE
Wesleyan University

SHEPHERD I. FRANZ
Government Hospital for the Insane

GILBERT V. HAMILTON
Frazysburg, Ohio

SAMUEL J. HOLMES
University of California

WALTER S. HUNTER
University of Kansas

HERBERT S. JENNINGS
Johns Hopkins University

GEORGE H. PARKER
Harvard University

EDWARD L. THORNDIKE
Columbia University

MARGARET F. WASHBURN
Vassar College

JOHN B. WATSON
New York City

WILLIAM M. WHEELER
Harvard University

PUBLISHED BI-MONTHLY BY
WILLIAMS & WILKINS COMPANY
BALTIMORE, U. S. A.

Entered as second-class matter April 4, 1921 at the post office at Baltimore, Maryland, under the Act of March 3, 1879

Price per volume, net postpaid { $5.00, United States, Mexico, Cuba
$5.25, Canada
$5.50, other countries

Made in United States of America

DIRECTORY
OF
American Psychological Periodicals

American Journal of Psychology—Worcester, Mass.: Florence Chandler.
Subscription $5. 600 pages annually. Edited by G. Stanley Hall.
Quarterly. General and experimental psychology. Founded 1887.

Pedagogical Seminary—Worcester, Mass.: Florence Chandler.
Subscription $5. 575 pages annually. Edited by G. Stanley Hall.
Quarterly. Pedagogy and educational psychology. Founded 1891.

Psychological Review—Princeton, N. J.: Psychological Review Company.
Subscription $4.25. 480 pages annually.
Bi-monthly. General. Founded 1894. Edited by Howard C. Warren.

Psychological Bulletin—Princeton, N. J.: Psychological Review Company.
Subscription $5. 720 pages annually. Psychological literature.
Monthly. Founded 1904. Edited by Shepherd I. Franz.

Psychological Monographs.—Princeton, N. J.: Psychological Review Company.
Subscription $5.50 per vol. 500 pp. Founded 1895. Ed. by James R. Angell.
Published without fixed dates, each issue one or more researches.

Psychological Index—Princeton, N. J.: Psychological Review Company.
Subscription $1.50. 200 pp. Founded 1895. Edited by Madison Bentley.
An annual bibliography of psychological literature.

Journal of Philosophy, Psychology, and Scientific Methods—New York.
Sub-station 84. Bi-weekly. 728 pages per volume. Founded 1904.
Subscription $4. Edited by F. J. E. Woodbridge and Wendell T. Bush.

Archives of Psychology—Sub-station 84, N. Y.: Archives of Psychology.
Subscription $5. 600 pp. ann. Founded 1906. Ed. by R. S. Woodworth.
Published without fixed dates, each number a single experimental study.

Journal of Abnormal Psychology—Boston: Richard G. Badger.
Subscription $5. 480 pages annually. Edited by Morton Prince.
Bi-monthly. Founded 1906. Entire field of abnormal psychology.

Psychological Clinic—Philadelphia: Psychological Clinic Press. Founded 1907.
Subscription $2.50. 288 pages annually. Edited by Lightner Witmer.
Without fixed dates (9 numbers). Orthogenics, psychology, hygiene.

Training School Bulletin—Vineland, N. J.: The Training School.
Subscription $1. 160 pp. ann. Ed. by E. R. Johnstone. Founded 1904.
Monthly (10 numbers). Psychology and training of defectives.

Journal of Educational Psychology—Baltimore: Warwick & York.
Subscription $4. 540 pages annually. Founded 1910.
Monthly (9 numbers). Managing Editor, J. Carleton Bell.
(Educational Psychology Monographs. Edited by Guy M. Whipple.
Published separately at varying prices. Same publishers.)

Comparative Psychology Monographs—Baltimore: Williams & Wilkins Company.
Subscription $6. 500 pages per volume. Edited by W. S. Hunter.
Published without fixed dates, each number a single research.

Psychoanalytic Review—Washington, D. C.: 3617 10th St. N. W.
Subscription $6. 500 pages annually. Psychoanalysis.
Quarterly. Founded 1913. Ed. by W. A. White and S. E. Jelliffe.

Journal of Experimental Psychology—Princeton, N. J.
Psychological Review Company. 480 pages annually. Experimental.
Subscription $4.25. Founded 1916. Bi-monthly. Ed. by John B. Watson.

Journal of Applied Psychology—Worcester, Mass.: Florence Chandler.
Subscription $4. 400 pages annually. Founded 1917.
Quarterly. Edited by G. Stanley Hall and L. R. Geissler.

The Journal of Comparative Psychology—Baltimore: Williams & Wilkins Company.
Subscription $5. 500 pages (approximately) per volume.
Bi-monthly. Edited by Knight Dunlap and Robert M. Yerkes. Founded 1921.

Gen.
Watr

CONTENTS

Number 1—February, 1922

The nature of unsuccessful acts and their order of elimination in animal learning. Zing Yang Kuo 1
Habit interference in the white rat and in human subjects. Walter S. Hunter 29
Coördination in the starfish. II. Locomotion. W. F. Hamilton 61
Book review 77

Number 2—April, 1922

Coördination in the starfish. III. The righting reaction as a phase of locomotion (righting and locomotion). W. F. Hamilton 81
The congenital sexual behavior of the young male albino rat. Calvin P. Stone 95
Fatigue effects as measured by sugar content of blood. Buford J. Johnson 155

Number 3—June, 1922

A tentative classification of the forms of animal behavior. S. J. Holmes .. 173
The ability of mudminnows to form associations with sounds. Florence Westerfield 187
Ability of *Pimephales notatus* to form associations with sound vibrations. Helen E. McDonald 191
The integrative character of habits. J. R. Kantor 195
The sensorial basis of music appreciation. Otto Ortmann 227
The relation of degree of Indian blood to score on the Otis intelligence test. Walter S. Hunter assisted by Eloise Sommermier 257

Number 4—August, 1922

The immediate psychological effects of tobacco smoking. David June Carver 279
A study of the spontaneous activity of the guinea pig. Edith E. Nicholls 303

Number 5—October, 1922

Attention, distraction and fatigue. F. C. Dockeray 331
The effects of cigar and cigarette smoking on certain psychological and physiological functions. I. Dart throwing. Robert Lee Bates 371

The instinctive locomotor reactions of the loggerhead turtle in relation to its senses. G. H. Parker........ 425

NUMBER 6—DECEMBER, 1922

The effects of cigar and cigarette smoking on certain psychological and physiological functions. II. Blood pressure and heart rate. Robert Lee Bates........ 431

THE NATURE OF UNSUCCESSFUL ACTS AND THEIR ORDER OF ELIMINATION IN ANIMAL LEARNING[1]

ZING YANG KUO

From the Psychological Laboratory of the University of California

The so-called unsuccessful movements in animal or human learning may be of two general types; they may be either ill-adaptive acts or merely excessive acts. By an ill-adaptive act is meant one that will either result in physical punishment or tend to check or disrupt the activity or the progress of the animal toward a consummatory reaction, such as food, or relief from confinement. By an excessive act is meant one that will neither do an injury to the organism nor will prevent it from reaching its goal, but that will, nevertheless, delay or prolong the process of consummatory reaction. Ill-adaptive acts as well as excessive acts may be of various degrees.

Our assumption is (1) that under normal conditions animals will eliminate ill-adaptive movements sooner than they will excessive movements, (2) that the order of elimination of ill-adaptive movements will be according to the degree of ill-adaptiveness, and (3) that the merely excessive movements may sometimes not be eliminated at all.

NATURE OF THE EXPERIMENT

To test out the above assumption an experiment was performed with 13 black and white rats. A "multiple choice" apparatus was used containing four compartments. One of these led the animal to the food box by a short path; another, by a longer path; another confined the animal for a period of time, and a fourth provided an electric shock punishment. For convenience of discussion we shall hereafter call these four compartments short-path compartment, long-path compartment, confinement compartment and electric-shock compartment, respectively.

---

[1] Invaluable suggestions and assistance were received from Dr. Edward C. Tolman. Read in part before the Western Psychological Association, August, 1921.

It was assumed that both electric shock and confinement were to be classed as "ill-adaptive." And, further, it was assumed that the electric shock was more ill-adaptive than confinement in that the former gives physical pain while the latter simply checks the animal's progress in getting food. And, finally, it was supposed that the entrance into the long-path compartment would be merely an excessive act when compared with the entrance into the short-path compartment. If, then, our original assumptions hold good, we would expect:

1. That the animal would eliminate the confinement compartment sooner than the long-path compartment.
2. That it would eliminate the electric-shock compartment more readily than the confinement compartment.
3. That on the whole rats would prefer the short-path compartment to the long-path compartment.

The figure shows the ground plan of the apparatus. The outside rectangular box, $R.S.T.U.$, is 38 inches in length and 36 inches in width; the inside rectangular box, $R.^1S.^1T.^1U.^1$, is 30 inches in length and 28 inches in width; the runways between the two boxes are 4 inches in width. E is the entrance door; D^1, D^2, D^3, and D^4 are spring doors. The inside box consists of four compartments (numbered *1*, *2*, *3*, and *4* in the figure).

The length of the compartment is one-half of the length of the inside box. Each compartment has two doors, one in the front and the other in the back. All the doors, including the entrance door and other spring doors, are tied with string so that the experimenter can close or open these doors by manipulating the strings. On the floor of all four compartments there are punishment grills connected with an induction coil outside the maze, The entire maze is constructed of unpainted $\frac{3}{4}$ inch redwood, 7 inches high, and is covered with wire mesh.

During the "preliminary" the animal is fed at O. During the actual experiment food is put either at F^1 or F^2. P is the position of the experimenter. By means of the spring doors the experimenter was enabled at will to make the animal go to the food box either by a long path or by a short path. For instance, if the food box was at F^2 and if the animal chose the long path compartment, the experimenter then opened doors D^1, D^3, and D^4, and the animal was obliged to go around the maze in order to get food. If, on the other hand, it chose the short-path compartment, door D^2 was opened and it would immediately get food by turning to the right.

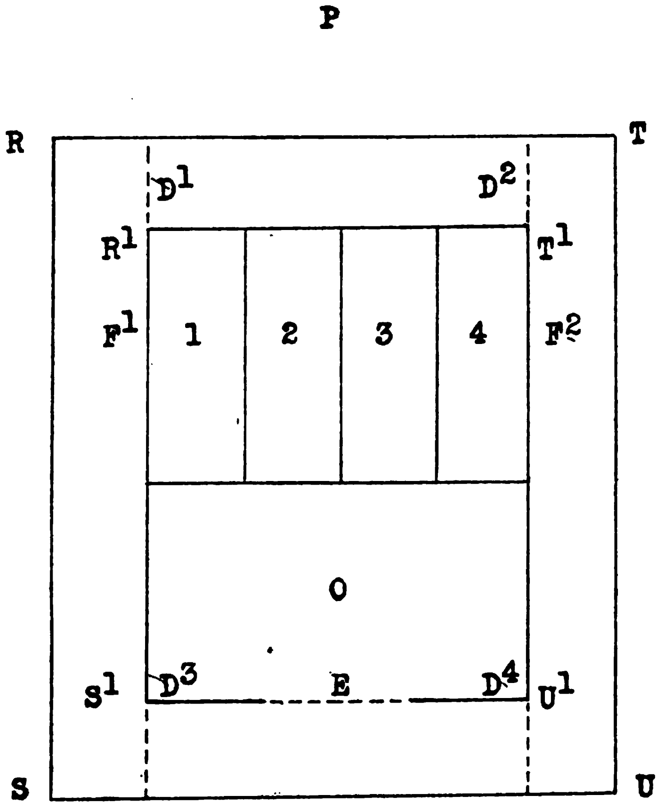


FIG. 1

Four groups of black and white rats were used as subjects. Group four consisted of four rats, the other three groups consisted of three rats each. All of these rats were young adult males, approximately three months old at the beginning of the

TABLE 1

Individual records of thirteen rats

TRIAL NUMBER	GROUP I			GROUP II			GROUP III			GROUP IV			
	Setting: Compartment 1—Long path Compartment 2—Electric shock Compartment 3—Confinement **Compartment 4—Short path**			Setting: Compartment 1—Confinement Compartment 2—Short path Compartment 3—Long path **Compartment 4—Electric shock**			Setting: Compartment 1—Short path Compartment 2—Long path Compartment 3—Electric shock **Compartment 4—Confinement**			Setting: Compartment 1—Electric shock Compartment 2—Confinement Compartment 3—Short path **Compartment 4—Long path**			
	Rat 1	Rat 2	Rat 3	Rat 4	Rat 5	Rat 6	Rat 7	Rat 8	Rat 9	Rat 10	Rat 11	Rat 12	Rat 13
	Compartment entered	Compartment entered	Compartment entered	Compartment entered	Compartment entered	Compartment entered	Compartment entered	Compartment entered	Compartment entered	Compartment entered	Compartment entered	Compartment entered	Compartment entered
1	3.1	1	2.4	2	1.4.2	4.1.2	4.3.2	1	4.2	4	3	3	4
2	2.4	2.1	2.4	1.4.3	1.2	4.2	4.3.2	4.1	3.2	1.3	2.3	1.4	1.4
3	2.4	2.4	2.2.3.4	1.3	4.3	2	2	3.1	3.1	2.3	4	4	3
4	2.1	2.2.2.1	1	4.3	4.1.2	4.2	1	1	2	3	1.4	2.4	2.4
5	2.4	1	2.2.1	3	1.3	2	1	1	2	4	4	1.2.4	1.4
6	3.1	2.3.3.4	3.2.4	3	2	1.3	2	2	3.2	4	4	4	2.1.4
7	2.4	3.2.4	3.4	4.3	1.1.2	3	2	2	1	4	3	4	3
8	4	2.1	4	3	2	4.3	2	2	1	4	4	4	3
9	4	1	2.4	2	3	3	2	3.4.2	1	4	3	4	3
10	3.2.3.2.1.	2.2.1	4	1.2	1.3	3	1	2	1	4	3	4	3
11	3.1	3.4	4	3	2	2	2	3.1	1	4	3	4	3
12	3.4	3.4	1	3	3	2	2	1	1	4	2.4	4	2.3
13	4	3.3.2.3.1	1	2	1.2	2	1	1	1	2.4	3	2.4	2.3
14	3.1	2.1	2.3.1	3	2	2	1	1	1	4	4	4	3
15	4	1	3.4	3	3	2	2	1	1	4	4	4	4
16	1	1	4	3	3	2	2	1	1	4	3	4	2.4
17	3.4	1	4	1.3	2	2	4.1	1	1	4	4	4	3
18	1	3.4	4	3	2	2	1	1	1	4	4	4	3
19	4	4	3.4	2	2	2	2	1	1	4	3	4	3
20	4	4	1	2	3	2	2	1	1	4	3	4	3

21	4	1	4	3	3	2	2	1	1	4	4	4	3
22	1	1	4	3	2	2	2	1		4	3	4	3
23	3.4	1	4	3	3	2	2	1		4	3	4	3
24	4	1	4	1.2	3	3	3	1		4	4	4	3
25	1	1	4	3	3	2	1	1		4	3	4	3
26	4	1	4	3	3		1			4	3	4	3
27	1	4	4	1.2	3		2			4	3	4	3
28	1	1	4	2	3		2			4	3	4	3
29	4	1	4	2	2		2			4	3	4	3
30	3.4	1	4	3	3		2			4	3	4	3
31	1	1	4	2	3		2			4	3	4	3
32	1	4	4	3	2		2			4	3	4	
33	4	4	4	2	3		1			4	3	4	
34	1	4	4	2	3		2			4	3	4	
35	3.1.4	1	4	2	2		1			4	3	4	
36	4	4		3	3		1			4	3	4	
37	1	4		2	3		1			4	3	4	
38	4	4		2	3		1			4	3	4	
39	3.4	1		2	3		2			4	3	4	
40	4	4		2	2		1			4		4	
41	4	1		2	3		1						
42	4	4		3	3		1						
43	4	1		3	1.2		1						
44	4	4		2	2		1						
45	3.1	4		2	3		1						
46	1	4		2	3		1						
47	1	4		2	3		1						
48	1	4		2	2		1						
49	3.4	4		2	2		1						
50	4	4		2	2		1						
51	1	4		2	2		1						
52	1	4		2	2		1						

TABLE 1—*Continued*

TRIAL NUMBER	GROUP I			GROUP II			GROUP III			GROUP IV			
	Setting: Compartment 1—Long path Compartment 2—Electric shock Compartment 3—Confinement Compartment 4—Short path			Setting: Compartment 1—Confinement Compartment 2—Short path Compartment 3—Long path Compartment 4—Electric shock			Setting: Compartment 1—Short path Compartment 2—Long path Compartment 3—Electric shock Compartment 4—Confinement			Setting: Compartment 1—Electric shock Compartment 2—Confinement Compartment 3—Short path Compartment 4—Long path			
	Rat 1	Rat 2	Rat 3	Rat 4	Rat 5	Rat 6	Rat 7	Rat 8	Rat 9	Rat 10	Rat 11	Rat 12	Rat 13
	Compartment entered	Compartment entered	Compartment entered	Compartment entered	Compartment entered	Compartment entered	Compartment entered	Compartment entered	Compartment entered	Compartment entered	Compartment entered	Compartment entered	Compartment entered
53	4	4		2	2		1						
54	1	4		2	2		1						
55	4	4		2	2								
56	1	4		2	2								
57	1	4		2	2								
58	1	4		2	2								
59	4				2								
60	4				2								
61	4				2								
62	4				2								
63	4												
64	4												
65	4												
66	4												
67	4												
68	4												
69	4												
70	4												
71	4												
72	4												
73	4												

experiment. They were in good health throughout. Great care was exercised in selecting subjects. Many rats were rejected on account of their not being docile; that is, being wild or excitable. We shall, in a later section, justify such procedure of selection. No rat selected had any training previous to the experiment.

Hunger was the primary motive used in the experiment. Other reaction tendencies such as curiosity, anger, and the like, were eliminated to a maximum degree either by the selection of subjects or by controlling the experimental conditions. Before the experiment was started the rats were given abundant food. Two days before the "preliminary" the food was reduced to a minimum and the same amount of food was given daily at the same hour throughout the experiment. No rat was fed outside the maze either during the preliminary or during the actual experiment.

During the preliminary period the rats were allowed to explore the runways of the maze while both the front and back doors of all the compartments were kept closed. This preliminary training usually lasted from five to six days. Great care was taken to look for any habitual disposition to enter one compartment rather than another before the training was begun, but no such preferential tendency was discovered.

The four compartments were so arranged that each of them could be used interchangeably as electric-shock compartment for one group of rats, as confinement compartment for another group, as long-path compartment for the third group, and as short-path compartment for the fourth group. Thus, no compartment was used the same way for two groups (for example, the same compartment was never used as confinement compartment for more than one group). The arrangements for settings of the four compartments for the four groups of rats will be seen on the top of each of the four main columns of table 1. The numbers 1, 2, 3, 4, in the "setting" column designate the compartment numbers as shown in the drawing of the apparatus.

When the animal was admitted by the entrance door *E*, he had to choose one of the four compartments in order to get food.

All the front doors were open while the back doors were closed. If the animal chose the short-path compartment the experimenter immediately lifted the back door and permitted him to go to the food box by a short path. If he chose the long-path compartment the experimenter lifted the back door and made the animal go to the food box by a round trip. If the electric-shock or the confinement compartment were chosen the experimenter immediately lowered the front door and in the former case pressed the key outside the maze thus giving the animal a shock, or, in the latter case confining him in the compartment for *twenty seconds*. The electric shock was strong enough to make the animal squeal every time and immediately jump back from the compartment after the shock was given. Great care was taken to prevent any injury to the animal's tissue. No rat seemed to have displayed any excitement or refused to work after the punishment, although hesitation to reenter the electric-shock compartment after the shock had been given was observed in many rats.

Each rat was given five trials per day. After the rat had learned to go to any given compartment consecutively for fifteen trials, without any error, the habit was considered as perfect and the experiment was discontinued.

RESULTS

Table 1 gives the detailed records of the four groups of rats. The figures in the first column represent the trial numbers. The figures in the other columns designate the compartment numbers entered by the rats on each trial; for instance, Rat 1 entered compartments *3* and *1* on the first which were set as confinement compartment and long-path compartment, respectively, for group I (rats 1–3). Rat 4 entered compartments *1*, *4*, and *3*, on the second trial which were set for group II (rats 4–6) as confinement compartment, electric-shock compartment, and long-path compartment, respectively.

Table 2 gives the number of the trial on which electric-shock, confinement and long-path compartments were last entered by each of the thirteen rats. *E.S.* designates electric-shock compartment; *C.F.* confinement compartment; and *L.P.* long-path compartment. Figures with parentheses represent the cases that do not follow the rule of the order of elimination found in this experiment.

The results show several important features:

1. *The electric-shock compartment was eliminated sooner than the confinement compartment.* On the average the last entrance into the former compartment occurred on the 7th trial (median, 6th trial), while the last entrance into the latter occurred between the 18th and 19th trials (median, 16th trial). For no rat did the last entrance into the electric-shock compartment occur after the 14th trial. The majority of the rats eliminated this compartment before the 10th trial. On the other hand, in rats 1 and 5 the tendency to enter the confinement compartment did not entirely disappear until after the 49th and 43d trials, respectively.

TABLE 2

RAT	E. S.	C. F.	L. P.	TOTAL TRIALS
1	10th	49th	58th	73
2	14th	18th	43d	58
3	14th	19th	20th	35
4	7th	27th	43d	58
5	4th	43d	47th	62
6	(8th)	(6th)	10th	25
7	2nd	17th	39th	54
8	(11th)	(9th)	(10th)	25
9	(6th)	(1st)	(6th)	21
10	2nd	13th		40
11	4th	12th	24th	39
12	5th	13th		40
13	6th	(16th)	(16th)	31
Average	7th	18th	28th	43
Median	6th	16th	24th	40

2. *On the whole, the confinement compartment was eliminated sooner than the long-path compartment.* On the average the last entrance into the long path compartment occurred between the 28th and the 29th trials (median, 24th trial). In rat 1 the

tendency to enter this compartment did not entirely disappear until after the 58th trial. On the other hand, the averaged last entrance into the confinement compartment was the 18th trial (median, 16th trial).

While the rule that the electric-shock compartment is eliminated sooner than the confinement compartment, and that these two compartments are eliminated more readily than the long-path compartment, holds good in the four groups of rats as a whole; there are some exceptions. In rat 6 the last entrance into the electric-shock compartment occurred on the 8th trial, while the confinement compartment was dropped out two trials earlier. Rat 8 did not eliminate the electric-shock compartment until the 11th trial, but on the 9th trial he made his last entrance into the confinement compartment, and on the 10th trial his last entrance into the long-path compartment. The last entrance into the electric-shock compartment and into the long-path compartment occurred on the same trial (6th) for rat 9, but this rat had ceased to enter the confinement compartment after the first trial. In rat 13, the entrance into the confinement compartment and long path compartment were eliminated simultaneously on the 16th trial. The deviation of the results of these four rats from the rule found for the experiment as a whole can be easily explained. We note that rats 6, 8, 9, and 13, are the quickest learners among the thirteen. Rat 9 masters the maze in 21 trials; Rats 6 and 8 in 25 trials, and rat 13 in 31 trials. This necessarily implies an earlier elimination of the long path compartment by these rats than that by others, although not necessarily an earlier elimination of the electric shock and confinement compartments. Table I shows that in every case the trial on which the entrance by these exceptional rats into the long path compartment last occurred is far below the median trial of the last entrance into this compartment for the group as a whole, and this is also true of their last entrance into the confinement compartment, with the exception of Rat 13, whose last entrance into the confinement compartment occurred on the median trial (16th trial) On the other hand, it will be noted that the rate of the elimination of the electric shock compartment was not accelerated by these rats. The earlier elimination of the confinement compartment and especially of the long path compartment by these rats tends to distort the order of the elimination of the three compartments commonly found in other rats.

3. All but two of the thirteen rats (10 and 12) finally chose the short path compartment (see table 1). And in many cases the shifting from the long path compartment to the short path compartment came about suddenly and in spite of frequency. After entering these two compartments alternately for a number of trials a rat might suddenly cease going to the long path compartment entirely and persevere in entering the short path compartment. The *suddenness* of the shifting from the long path compartment to the short path compartment is especially marked in rats 5, 6, 8, and 9. And the occurrence of the shift in spite of a greater accumulated frequency for the long path compartment is especially notable in rats 2, 4, 5, 7, and 9. In rats 6, 8, and 11 the number of times of entrance into both compartments was equal when they began to cease entering the long path compartment.

4. Two rats (10 and 12) never made the shift from the long path compartment to the short path compartment. Rat 10 never went to the short path compartment after the fourth trial while rat 12 never went to it after the first trial. The number of trials in these two rats was extended to 40 (see table 1), but there was no indication that they would chance to enter the short path compartment since the habit of going to the long path compartment seemed to be fixed. Such cases must not, however, be interpreted as altogether of the nature of a failure on the part of these rats. The records of the other rats indicate that they tended to enter both the short path compartment and the long path compartment alternately, for some time, after which they eventually chose the former and discarded the latter. But since rat 12 never entered the short path compartment after the first trial, and rat 10 never after the fourth trial, in their case there was little opportunity for this shift.

We may now present a more detailed analysis of the frequencies of the different compartments and the shift from compartment to compartment.

Table 3 shows the total number of the entrances by thirteen rats into each of the four compartments in each *trial period.* The first twenty trials are divided into four *trial periods,* thus making five trials to a period; the next twenty trials (from the 21st to the 40th trial) are divided into two periods, (ten trials in each period) and from the 41st trial up all trials are grouped in one trial period.

Considering the results for each compartment individually and in comparison with the others the following points appear:

TABLE 3

	TRIAL PERIODS						
	1-5	6-10	11-15	16-20	21-30	31-40	41 up
Entrances into the E. S. compartment	34	15	4	0	0	0	0
Entrances into the C. F. compartment	18	15	16	6	4	2	3
Entrances into the L. P. compartment	34	38	31	26	57	41	19
Entrances into the S. P. compartment	31	27	34	39	55	44	86
Total	117	95	85	71	116	87	108

a. The electric shock compartment

The total number of entrances by the 13 rats into the electric shock compartment in the first trial period is equal to their total number of entrances into the long path compartment, but greater than their total number of entrances into the confinement compartment or into the short path compartment. But in the second trial period their total number of entrances into this compartment is greatly decreased. In the third period (from trial 11th to trial 15th) the total number of entrances into this compartment is still further decreased.[3] The number of entrances into the compartment in the fourth period is nil, and no recurrence of entrance into it took place thereafter.

---

[3] The individual record not presented here shows that ten rats never entered it in this trial period.

b. The confinement compartment

The total number of entrances by all rats into the confinement compartment in the first trial period is smaller than their total number of entrances into any other compartment in the same period. In the second period the total number of entrances by all rats into the confinement compartment is slightly decreased; in the third period the total number is a little greater than that in the second period. From the fourth period on the total number is gradually decreased. Seven rats eliminated the compartment after the third period; and twelve after the fifth period.

It is interesting to note that the tendency to enter the electric shock compartment disappears not only very early but very suddenly, whereas the tendency to enter the confinement compartment dies out rather gradually and slowly. Furthermore, the individual record shows that the entrance into the former never recurs after the tendency has been inhibited, whereas in some rats the tendency to enter the latter may occasionally recur after a period of disappearance.

c. The long path compartment

The total number of entrances by all rats into the long path compartment is greater than that of entrances into the short path compartment in the first trial period. From the second period to the sixth period the situation is rather fluctuating. The total number of entrances into the long path compartment may be increased in one period and decreased in another; the number of entrances into the compartment by all the rats is greater in the second and fifth periods but smaller in the third, fourth, and sixth periods than the number of entrances into the short path compartment. In the last period the total number of entrances by all rats into the long path compartment is greatly decreased, while that of entrance into the short path compartment is greatly increased. This is due to the fact that all rats had chosen the latter compartment during this period.

We conclude that frequency and recency as such have very little to do with the matter of elimination in this experiment. This can be easily seen from table 1.

THEORIES OF LEARNING IN ANIMALS

The results of our study immediately raise the mooted question in animal behavior; namely, "Why an animal learns, or why the so-called unsuccessful acts are rejected and the successful ones are selected; or, to put it more specifically, why ill-adaptive acts are eliminated sooner than the excessive ones, and why the excessive acts may not always be eliminated? Before we state our own point of view with regard to this question we shall make a critical examination of the theories that have been suggested by various writers for the explanation of learning in animals.

The pleasure-pain theory is perhaps the oldest. There is little need for any outline of the theory here. The opponents of the theory have charged its advocates with being subjectivistic and interactionistic. The charge is so far well grounded; indeed many of the exponents of the pleasure-pain theory have been committed to a mentalization of animal behavior.

The fact that a painful stimulus tends to cause avoidance and a pleasurable stimulus tends to encourage approaching, I think no one will deny. But the pleasure-pain theory does no more than state this empirical fact. It does not tell us why the pleasureable acts are selected and the unpleasurable ones rejected. In other words, the theory is simply a restatement of the problem rather than a solution of it. Furthermore, as Carr[3] and others have pointed out, not all rejected acts are unpleasant, neither are all selected acts pleasant.

Primarily in order to avoid the interactionist implications of the pleasure-pain theory, Hobhouse[4] suggests the theory of confirmation and inhibition for explaining animal learning. Reviewing this theory Holmes says "It is essentially a theory of how behavior comes to be adaptively modified through the formation of association. It makes no attempt to explain why pleasure is associated with certain experiences and pain with others."[5]

---

[3] Principles of Selection in Animal Learning, Psychol. Rev., xxi, 169. 1914.

[4] Mind in Evolution, 1915.

[5] Studies in Animal Behavior, 1916, pp. 134–135.

Holmes here seems to have clearly pointed out that what we need to explain is the question "why certain responses tend to be repeated and others tend to be inhibited." But neither has Holmes been successful in answering the question which he has well raised in his criticism of Hobhouse's theory. According to him, "A response which results in setting into action a strong instinctive proclivity is reenforced or inhibited, as the case may be, according to its congruity or incongruity with the proclivity thus aroused."[6]

Nothing is gained by Holmes' theory except that he substitutes a pair of terms "congruous" and "incongruous" for "successful" and "unsuccessful." He here also falls back to the mere description of the nature of the rejected acts and selected acts. Acts are selected or rejected because they are "congruous" or "incongruous." But why are congruous acts selected and incongruous ones rejected? To this question Holmes gives us no answer. He has attempted to explain the selective agency in animal learning but he got nowhere! Moreover, just as not all selected acts are pleasant and not all rejected acts are unpleasant, so not all the former are congruous and not all the latter incongruous; many trivial or superfluous acts that are neither congruous nor incongruous may be selected or rejected.

J. Peterson proposes the principle of 'completeness of response' as an explanation of learning.[7] "In the case of the maze problem the animal on entering a *cul de sac*, or any other path in fact, responds at first more or less incompletely because all the subordinate activities cannot take place at once. If the animal's progress is soon checked in a blind alley the animal is not seriously nonplussed, certain elements of the general response are tending to drain into other alleys that recently have been passed, thus partially dividing the animal's activity. These elements now prevail when the others are checked. Let us suppose that the correct path A has just been passed when the animal suddenly comes to the end of the *cul de sac* B. The tendencies to respond to A are still surviving and now direct the impeded activity into this the successful path. If, on the other hand, the correct path had been chosen the first time the distracting impulses toward B would have become fainter and fainter as the animal proceeded into A and would finally fade away."[8]

---

[6] Op. cit., pp. 148–149.

[7] Completeness of Response, etc., Psychol. Rev., xxiii, 153-162. 1919.

Peterson's theory has several difficulties. In the first place, is it necessary that the impulses toward the correct path A should be actually present when the animal enters the blind alley B or *vice versa?* I think it is highly probable that in many instances the animal would go straight ahead to one path without the presence of some antagonistic tendencies which tend to drain into other paths. Secondly, why is it that when the animal enters the correct path A the first time the tendencies to go to the blind alley B become fainter and fainter and would finally die out, whereas the tendency to go to the correct path A still persists even when the animal begins by choosing the blind alley B? This is a very crucial point which Peterson does not explain. Third, if the animal turns back to A after he comes out of B because the tendencies toward A were already present and still persist during his entrance into B, rather than because these tendencies are aroused by the new sensory situation which results from the very act of the entrance into B, it will be difficult to understand "how, on the grounds alleged the tendencies along the true path, which were not strong enough to keep the animal from entering the blind alley, could gain sufficient strength, once the animal had been in and come out of the blind alley, to prevent its reentering it."[9] And, finally, if completeness of response *per se* is responsible for selection and elimination, we should have no right to expect the animal to prefer a short path to a longer one—which is a fact which has been confirmed by the writer in the experiment reported in this paper and also by De Camp.[10] Surely the tendency to go through a long path is at least as completely expressed or performed, as far as the discharge of nervous energy is concerned, as is the tendency to go through the short path.

---

[8] Psychol. Rev., Op. cit., pp. 155–156

[9] R. T. Wiltbank, The Principles of Series and Completeness of Response as Applied to Learning. Psychol. Rev., xxvi, 281, 1919.

[10] Psychobiology, ii, 245–254. 1920.

In contrast to the above views there is a second type of theory for the explanation of learning offered by another group of students in animal behavior. This new type of explanation is based upon the prinicple of the conditioned reflex. But this principle, as other views stated above, is a description rather than an explanation of learning.

Let us turn now to another theory, that of Watson. Watson would have us believe that frequency and recency are the chief factors in selection and elimination in animal learning. As is well known, his chief argument is based upon the law of chance. He contends that simply as a matter of chance and the mechanics of the situation at the beginning of any new trial the successful act is the most recent act and has occurred the most frequently. Our own experimental data, however, do not seem to support this contention. Many rats learned to select a correct path not only *not* because of recency or frequency, or both, but in spite of them. As has been pointed out, recency has very little to do with the elimination of errors in the experiment reported in this paper. The findings of our experiment are sufficient to refute Watson's theory; we need not point to the empirical fallacy of his application of the mathematical law of probability to which he has committed himself.[11]

Carr would add to the principles of frequency and recency the principle of sensory intensity.[12] The same criticism which was raised against the views of Hobhouse, Holmes and Peterson may be applied to Carr's theory of sensory intensity; that is, he merely describes in his own fashion the nature of the successful and unsuccessful acts.

While the pleasure-pain theory, the theories of confirmation and inhibition, of congruousness and incongruousness, and of completeness of response, of conditioned reflex and of sensory intensity have described more or less adequately the nature of the selected and rejected acts, and have explained rather nicely how certain sensory-motor associations are formed, and while the principle of recency and particularly of frequency have explained how a habit is fixated, they have all failed entirely to give an adequate account for a selective agency, "which preserves or repeats certain activities and rejects others on the basis of their results,"[13] to use Holmes's own expression again. We do not mean here, however, to reject all these theories as wholly ungrounded, but rather to call attention to the fact that further analysis of the situation should be made so that a more adequate account for the selective agency can be given which will in no way contradict any of the above theories. Such an analysis will consist (1) of a distinction between the fixation of habit and elimination of errors; (2) the nature of the principal response and its relation to the subordinate acts, and (3) the determination and control of the principal response in the laboratory. Let us first take up the distinction between the fixation of habit and elimination of errors.

---

[11] See Dashiell's article, The Need for Analytic Study of the Maze Problem. Psychobiology, ii, 181–186. 1920.

[12] Principles of Selection, etc., Op. cit., pp 157–165.

1. By fixation of habit is meant the *becoming automatic* of an act. By elimination of errors we mean the *selection and rejection* of acts. Acts may be selected or rejected by the animal at the early period of learning and yet they may not at once reach the automatic stage. It is only after a number of repetitions that they gradually become automatic; that is, fixated. That frequency is chiefly responsible for fixation of habit no one will deny. But frequency *per se* has very little to do with elimination of errors. Observations of the behavior of rats in a maze shows that in choosing a correct path a second time they do not go at it blindly, that is to say, they do not choose it as a result of mere previous frequency. In my experience after they have been disappointed a number of times in getting food by an incorrect compartment, they hesitated to enter that compartment when they happened again to go before its door, and after hesitating turned to the right compartment. Some of them half entered the wrong compartment but hastily withdrew

---

[13] Jour. of Compt. Neurol. and Psychol., Op. cit., p. 147.

and then went immediately into the right compartment; others passed by the incorrect compartment without even paying any attention to it. Such tentative non-automatic seeming choices were observed only during the beginning of the experiment; they disappeared after a correct compartment had been chosen and repeatedly entered for a number of trials; i.e., after fixation had set in.

That 'accuracy' which is, of course, the result of the elimination of errors, is something quite distinct from 'automaticity' which is the result of frequency, has been demonstrated by Miss Vincent's experiment on visual control in rats.[14] In this experiment she found that at the beginning of learning, before the rat's attention was freed, the choice of a correct path largely depended upon visual control, but after the problem had been learned kineasthetic functions gradually took the place of visual function and the act became automatic. She found also that in times of momentary distraction vision resumed its potency and the result was "a less perfect automatism and a slower speed." This shows clearly that accurate movement and automaticity (fixation) do not necessarily go together. So long as accurate movement is dependent upon visual control it indicates that 'fixation' has not set in or is momentarily disrupted.

In the case of human learning the distinction can be more readily seen. In the acquisition of a new skill a person may, through imitation or verbal instruction, be able at the beginning of learning to execute the performance as accurately as might be desired. But this can only be accomplished by great effort of attention. Here again, as in the case of the rats used in Miss Vincent's experiment, visual control plays a very important part in making correct movements. It is obvious that when attention is high or effort is great the act is not "fixated" and the speed of the performance is slow. Automaticity or fixation✓ of habit is characterized by the decrease of effort or lessening of attention, by the gain in speed, and by the fact that the act is taken care of more by kinaesthetic and tactual function than by vision. Of course, such an automatic stage can be reached only after numerous repetitions.

---

[14] Jour. of Animal Behavior, v, 1–24.

The distinction between fixation of habit and elimination of errors might perhaps have been very obvious to every one were it not for the fact that Watson insists on making frequency and accuracy alone responsible for elimination in maze learning,[15] for in so doing he obscures this distinction. Since our experimental findings and observations of the rats' behavior have clearly shown that frequency has very little to do with elimination, we are obliged to draw such a distinction and to seek for a more fundamental factor which is sufficient to explain learning. What, then, is this fundamental factor? This question leads us to a consideration of our second proposition; namely, the nature of the principal response and its relation to the subordinate acts.

2. The nature of the principal response and its relation to the subordinate acts have recently been well discussed by a group of writers (Perry,[16] Tolman,[17] and Woodworth[18]). Although these writers differ from each other in detail, the main motive of their attempt is essentially the same; namely, the desire to allow, in a purely mechanical and objective way, for the purposiveness which they would claim is inherent in and fundamental to learning. According to them the selective agency is a drive[19] (Woodworth), higher propensity (Perry), or determining adjustment (Tolman). This drive sets the organism in a state of readiness—bodily attitude or motor set. "Once aroused and not immediately satisfied" it acts as a determining tendency and excites certain varieties of subordinate responses and inhibits others. The subordinate acts or preparatory reactions are "means"—reactions, which are excitable by the drive and may serve to bring about the consummation of the end—reaction. These subordinate acts are selected or rejected according to their consequences with reference to the consummatory reaction.

---

[15] Behavior, pp. 267–268.

[16] Docility and Purposiveness. Psychol. Rev., pp. 1–20. 1918.

[17] Instinct and Purpose. Psychol. Rev., pp. 217–234. 1920.

[18] Dynamic Psychology. Columbia Univ. Press. 1918.

[19] I am inclined to think that this drive is acquired rather than inherited. See Jour. of Philos., xviii, 645–664, 1921.

Here we seem to have a somewhat adequate view regarding the selective agency in learning, a view which has been partially or wholly overlooked by all of the other writers whose doctrines with regard to the problem have been discussed in the foregoing pages. This mechanical interpretation of purpose does not, I think, necessarily suppose any presence of the ideational process or any psychical elements in the animal. The exponents of this theory, if I mistake not, are willing rather to characterize the "drive" in terms of muscle tension, motor set, and the like.

Unfortunately these writers have made no attempt to analyze the experimental conditions which bring about and intensify the determining tendency so as to make it prepotent in the situation. Such an analysis is of great import from the standpoint of animal experimentation, for the success of an experiment in animal learning depends to a great extent upon our ability to control the incentive of the animal. The reaction tendencies first evoked by the new environment may be undesirable for rather than helpful to learning. The food seeking trend is most frequently looked to to produce learning. Yet it may not necessarily dominate the situation at the beginning of the experiment. Curiosity which results in exploratory movements; fear which often results in excitability or escape movements; anger (as possibly in the case where the cat is confined in a box) which results often in violent reactions or escape movements, and probably some other reaction tendencies, are more likely to be prepotent at the beginning of an experiment. In fact in a great many rats the food seeking tendency is often completely held in abeyance by other reaction tendencies, particularly curiosity and excitability, during the first few days in the maze. In my own observations many rats were at first too much "excited" by the new environment to care for food even though they had not been fed for twenty-four hours. Such a state of excitement often lasted for two or three days—even longer.

But since these exciting tendencies may not be desirable for experimental purposes the attempt is usually made to reduce them to a minimal degree on the one hand, and intensify the food seeking trend on the other. This is attempted by the so-called "preliminary." During the preliminary an animal is put in the maze to make him familar with it so that curiosity, fear, etc., will not be aroused when the actual experiment is begun. Besides, during this period of preliminary the attempt is made to regulate the degree of hunger and the animal is fed in the maze (and nowhere else) so that it will acquire the habit of seeking for food when in the maze. In experiments where there has been no preliminary it is doubtful whether the food seeking trend dominated the situation at the beginning of the experiment. In Thorndike's experiment with kittens it is clear that the tendency to escape which resulted from fear or anger was prepotent at first—or at least mixed with hunger—and it was only after a number of trials that the former tendency gave way to the latter. In short, the purpose of the preliminary should be to make the animal adapt itself to any distracting stimuli so that reaction tendencies which will tend to interfere with learning will not be aroused.

The control of the motivating tendency for learning is not always successful. The animal may have acquired very strong tendencies of curiosity, fear, and the like, which tend to dominate over other trends and which cannot be easily suppressed by the experimental conditions. Animals of this type may be termed 'indocile,' meaning that they are uncontrollable in that the desired tendency for learning cannot be strengthened and the strength of the undesirable tendencies cannot be minimized. This will partially explain why some animals fail to learn at all; these animals are usually "indocile." And it will justify our procedure of selecting subjects for the experiment reported in the foregoing pages where many rats were rejected on account of their extreme excitability. (See above, page 7.) Failing to learn, however, may sometimes be due to lack of efficiency on the part of the experimenter to control the experimental conditions so as to reenforce the desired tendency.

If such an interpretation is correct, we can easily see why some of the rats learn more readily than others. There are three factors for quick learning; (1) controlability on the part of the learner, (2) readiness or plasticity of its nervous system to form associations, and (3) skill on the part of the experimenter in manipulating the experimental conditions which tend to facilitate on the one hand the reaction tendency desired for learning, and inhibit the disturbing tendencies on the other. In our experiment where many rats mastered the problem readily it may be due to the fact that especially great care was taken in selecting subjects, in regulating hunger, and in controlling other sensory stimuli.

In maze learning in addition to the food seeking trend which we utilize as the main motivating tendency in learning, we sometimes arouse in the animal the fear reaction tendency, so that certain alleys which require negative reaction will be eliminated more readily. This is usually accomplished by electric shock punishment. In administering the electric punishment great caution should be taken against the over arousal of the fear response. In some cases, either due to lack of skill in administering punishment or to the excitability of the rat, the fear response is so aroused that the animal displays violent action or is paralyzed and refuses to work so that the experiment has to be abandoned. In such cases the drive has been shifted; the fear response becomes prepotent and the food seeking trend is momentarily suppressed. There is some justification for those who object to the use of electric punishment; for unless it is carefully managed it is likely to result in a shifting of the drive which may tend to interfere with learning.

In some experiments, however, the fear reaction tendency may be used as the sole motive in learning. In Glaser's experiment, quoted by Watson, "where rats were dropped into hot or cold water and allowed to find an entrance, it was shown that the animal formed the habit of turning correctly in the hot or cold water and finally reaching the exit."[20] In such cases the sole drive in learning was "the tendency to escape." Such a tendency was so strong that the animal was "driven" to face an unpleasant experience—hot or cold water—an experience which he would ordinarily avoid.

---

[20] Op. cit., pp. 256–257.

Only after the drive desired for learning has been definitely secured can we divide the subordinate acts into two groups; namely, successful and unsuccessful acts. The successful and unsuccessful acts are referred to only from the standpoint of the consummatory reaction; only when an animal is seeking food can we call an act which will interfere with or prevent the animal from getting food an unsuccessful act. The same subordinate acts may be aroused by fear, curiosity, hunger, or other determining tendencies. But whether or not they are successful acts depends upon the consequences they bring about with reference to the determining tendency. All those terms such as correct or incorrect path, useful and useless movements, and a host of others of similar meaning that are inevitably employed in animal experimentation, refer to the purpose of the experimental conditions which are arranged by the experimenter so as to create or bring about a purposive reaction in the animal; otherwise they are all meaningless. Again, the nature of the sensory consequences of an act can only be understood in the light of the determining tendency. Carr says, "The blind check, thwart, and suppress activity more than does the true path while the latter encourages and facilitates activity more than does a blind alley."[21] Yet this is true only with reference to the food seeking trend. If the animal is well fed and well familiar with the maze the entrance into the blind alley or a confinement compartment may not produce such sensory consequences as Carr here describes; indeed were he not hungry he may lie down in the blind alley or in a confinement compartment and comfortably sleep there. And, furthermore, all the concepts of congruousness or incongruousness, completeness or incompleteness, and annoyance or satisfaction of response will have meaning only when they are interpreted in terms of the principal response. Our chief objection to these concepts lies in the fact that their advocates have failed to explicitly or sufficiently refer them to the purposive conditions of the experiment, or to the determining tendency which is produced by such conditions.

[21] Op. cit., p. 162.

The suppressed tendencies undesirable for learning may occasionally recur. Their recurrence may be due to momentary distraction by new sensory stimuli or by old stimuli to which the animal has not responded for a period of time. It may also be due to some changes taking place in the organism itself, or to some other disturbing factors outside the maze. The recurrence of the suppressed tendencies often tends to momentarily discontinue the process of habit formation which is being gradually built up. Great effort should be made to readjust the experimental conditions in every possible way so that the undesired tendencies will again be put under control.

Let us, now, turn once more to our discussion of the distinction between fixation of habit and elimination of errors, and restate it in the light of our experimental results. We have seen that the drive or determining tendency which moves the organism toward certain consummatory reactions excites a variety of subordinate responses and selects or rejects them on the basis of their results. An important point in this connection which has been brought out by Perry, and particularly emphasized by Tolman, is that there is a great deal of variability among the subordinate responses. These different acts may vary in their sensory effects with reference to the consummatory response; that is, some of them may be ill-adaptive, some irrelevant or excessive, others successful or essential, and, as has been pointed out, all ill-adaptive acts as well as excessive and essential acts vary greatly in degree. Now, if the differences in the degrees of ill-adaptiveness and excessiveness of various subordinate acts are discernible to the animal, (we are not here assuming any presence of consciousness) it will, other things being equal, eliminate these acts accordingly; that is, the ill-adaptive acts will be eliminated sooner than the excessive ones, and the more ill-adaptive ones sooner than the less ill-adaptive ones, and the more essential ones are often preferred. Thus, we have found in our experiment that the electric shock compartment is rejected more rapidly than the confinement compartment, and that these two compartments are eliminated sooner than the long path compartment, and we have confirmed De Camp's findings that within certain limits rats often choose a shorter path.

Here it is obvious that the ill-adaptive acts tend to prevent the organism from, or to disrupt the process of its activity toward, the consumatory response, and hence the muscular tension which is set toward that end-reaction is not released but instead it is likely to be intensified by such a prevention or disruption. And, furthermore, the electric shock, provided it does not produce any violent action or paralyze the animal, gives additional emotional reenforcement which tends to produce in the rat a quicker avoidance reaction (in such case, be it remembered, an additional reaction tendency; namely, fear, is aroused to coöperate with the main tendency; namely, the food seeking trend.[22] On the other hand, the excessive act does not produce any such sensory consequence, there being no disruption of the rat's activity or, in other words, it will eventually bring the animal to the food and hence releases the muscular tension. It is these differences in their consequences with reference to the principal response that account for the order of elimination as found in our experiment.

It must be admitted, though, that the rule of the order of elimination of the unsuccessful acts may be applicable only to such simple conditions as those in our experiment under which the rat is made capable of discriminating the differences between ill-adaptive and excessive acts. On the other hand, if the experimental conditions are so complicated as to throw the animal into confusion, or if the sensory effects of all the unsuccessful acts are equally or nearly equally the same (for instance, the same degree of punishment is given for every wrong choice, or if there is no punishment used in the experiment), the rule may be distorted and the rat may eliminate the errors in a random order or by some other factor such as, for example, recency, frequency, etc. In the case where no punishment whatever is used for wrong choice,[23] recency, and more particularly frequency, may affect in a negative way; that is, the blind alley which is entered most recently or most frequently is likely to be the most difficult one to be eliminated.[24]

---

[22] The greater advantage of a combination of the two stimuli has, of course, been previously established by Yerkes and Dodson. Cf. Jour. Comp. Neurol. and Psychol., 1908, xviii, pp. 57–491.

Thus far we have been discussing the process of elimination of errors. Just one word more concerning the fixation of habit. In the early period of learning the rejected acts may occasionally recur or there may appear some new acts and, moreover, the selected acts may not at all times occur in a definite order. During this period of learning rats are more likely to be distracted by new sensory stimuli than they are during the later period. All this is due to the fact that the sensory motor associations have not been fixed and the separate successful acts have not been integrated. Now, after a number of repetitions, the associations are made more and more firm, and the whole series of the successful acts become integrated into a *chain response* and they will appear every time in a more or less definite and fixed order. Such is the process of fixation; it is essentially a process of the integration of the *selected* acts.

---

[23] In such case any unsuccessful movement must be regarded as excessive rather than ill-adaptive.

[24] Cf. Behavior, p. 288 (footnote) and also Peterson, Learning when Recency and Frequency Factors are Negative, Psychol. Bul., xxviii, 80–18, 1921.

HABIT INTERFERENCE IN THE WHITE RAT AND IN HUMAN SUBJECTS

WALTER S. HUNTER

The University of Kansas

INTRODUCTION

The first specific studies of habit interference in animals below man were published in 1917 from the psychology laboratory of the University of Texas by Hunter and Yarbrough[1] (1) and by Pearce (2). These studies had the merit of using simple opposite responses in a T-shaped discrimination box and of using stimuli whose mutual physical and physiological relationships could be approximately indicated. The interference situation was thus under control in a way impossible with the customary problem boxes and mazes. The results of the experimentation, using both sound and light as stimuli, may be summarized as follows: (1) The formation of one simple habit may seriously interfere with the formation of a second habit. Where the two habits involve antagonistic responses to physically different but to physiologically equivalent stimuli, the first habit may all but block the formation of the second one. (2) The formation of the second habit does not interfere with the retention of the first habit. A similar situation has been indicated for humans by Bair and by Muensterberg. It is also involved in studies of retroactive inhibition. Thirty days of diverse training here failed to influence the retention of the first habit. (3) If interference be stated in terms of a comparison of the first part of the curves of the two habits, then the interference may or may not reveal itself during the first six-tenths of learning.

---

[1] Preliminary reports were given by these psychologists and by Wylie at the meeting of the American Psychological Association, December, 1915, and published in the Psychological Bulletin, 1916, vol. 13, pp. 78–9.

Webb (3) in 1917 published an important study of transfer of training and retroaction in rats and humans using mazes. Five different maze patterns were used with rats and three types of pencil mazes with humans. Experimental conditions for the two groups of subjects were, so far as possible, comparable. Webb's study dealt with the following problems: (1) the presence or absence of transfer; (2) the dependence of transfer upon the nature of the first and of the second problems; (3) the locus of the transfer effect in the curves of learning; (4) the relationship between performances in the two classes of subjects; and (5) the possible retroactive effect of one activity upon various activities and vice versa. Webb's study is important not alone because of its factual contributions, but also because it is the first systematic study of the problem with the maze.

The results secured and the conclusions arrived at may be briefly indicated: (1) Practically no cases were found of habit interference when total time, errors and trials were the criteria considered. This was true although an effort was made to secure conditions in certain of the mazes which would produce negative transfer. (2) The factors influencing the degree of transfer were found to be: *a*, the nature of the first habit; *b*, the nature of the second habit; *c*, the degree of similarity between the mazes (similarity judged by psychologists and also by the difficulty of mastery); and *d*, the direction of transfer. (3) Curves were presented showing the average records for the first five trials of each habit. The conclusion was drawn that the transfer effect has its locus in the first five trials of the second habit or, stated in other terms, that the animal starts the second habit at the approximate level attained at the fifth trial of the first habit. (4) The laws and conditions of transfer were found essentially identical for humans and for rats. The greatest and also the least amounts of transfer were found in the same maze combinations for the two classes of subjects. An additional fact of the very greatest importance drawn from the experiments on retroaction should be listed here. The experimental procedure was to have the subjects master a given maze, work thirty days on a second maze, and then be re-tested on the first maze. Control groups were run with a thirty-day rest period between learning and relearning. *There was no correlation between learning and relearning for either rats or humans.* This was found to be the case in numerous experiments and can be taken as clearly established—due consideration being given to the small number of subjects (5–10) in each set and to the experimental conditions involved. Human subjects showed a slightly higher retention of the first habit than did rats. (5) Some evidence for a slight retroactive effect was found using the method just described. This is at variance with the results secured by Hunter and Yarbrough who secured negative results with auditory habits using a thirty day interval.

In 1919 Wylie (4) published a study of the transfer of response in the white rat which, like the studies of Hunter, Yarbrough and Pearce, emphasized the control of the sensory and motor sides of the types of behavior involved. Wylie trained rats to avoid either a visual, an auditory, or a painful stimulus. After this habit was set up for the given stimulus, one of the other of the three was substituted and the habit of avoiding it was established. The data so secured made it possible to compare the readiness with which a certain response was set up to a given stimulus with or without previous training on a different stimulus. Wylie says (p. 63): "It again stands out clearly that it is an advantage in learning one sort of stimulus to have first learned the same response to another sort of stimulus." Again he says (p. 64) "that even in some situations the learning process for one sort of dominant stimulus is actually reduced in length so much by first introducing another dominant stimulus, that the time and effort for both is less than for the one alone." The amount of transfer was indicated by the amount of saving in the total number of trials required for learning under the various conditions. When the end of the curve for one habit was compared with the beginning of the curve for the following habit, negative transfer or interference was evident.

Hunter (5) in 1918 repeated Wylie's experiment in which stimuli from other senses were substituted for the accustomed stimulus and the response left constant. A T-shaped discrimination box was used. Rats that had formed the habit of turning to the right for a piston-whistle sound and to the left for silence, failed to substitute a tuning fork sound for that of the whistle. However, when a light was substituted for the whistle the transfer was promptly made and the same response given to the light that had been given to the one sound. No transfer was made (within the limits of training used) when the rough tactual stimulation of sandpaper was substituted for the sound of the whistle.

Wiltbank (6), 1919, continues and corroborates parts of Webb's work. Five groups of rats (8–10 per group) were tested upon five mazes in order to throw light upon the following problems: What is the effect upon the learning of a given maze of the previous learning of another maze? Does the effect persist and is it cumulative through a series of mazes? What is the effect when one or the other maze is incompletely learned? What is the effect upon relearning of having mastered four intervening mazes? The results secured show: A positive transfer from one maze to another in both time and errors and in trials with the exception of two cases of negative transfer, or interference, when measured by the latter criterion. (No comparison of the curves is made to indicate the locus of the transfer.) This positive transfer was not due to a gain in such identical quadrants of the maze as were present. There is no evidence to indicate that the amount of transfer tends to be greater from the more to the less difficult maze. The transfer, save in two cases, was not only positive but persistent, although it was not cumulative and did not increase with the increase in the number of mazes learned. The transfer effect between two mazes when the first is but partially learned may be detected by the criterion of time when but two trials have been given in the first maze. The criteria of trials and errors were not so sensitive. When a maze is retested after an interval during which four mazes were mastered, a saving rarely appeared. No data were available to indicate whether the lack of saving was due to interference or to disuse. Correlations were made between savings in time, errors, and trials. Trials and errors gave the highest coefficients (0.70

to 1.00). Trials and time and errors and time gave coefficients ranging from −0.40 to 0.80. The particular data correlated are inadequately described and no emphasis was placed upon the results. I have been unable to understand them clearly.

Brockbank (7), writing in 1919, presents data upon habit interference in the rat. Animals who had mastered the circular maze did not have their retention decreased after a period of thirty days by being trained during that period upon a rope-ladder problem. (This is at variance with data secured by Webb and summarized above.) Brockbank also presents data indicating that training on such diverse problems as the sawdust box and a rope-ladder problem will improve the ability to acquire the maze habit.

The net result of the above researches may be summarized as follows:

1. Both positive and negative transfer between habits have been demonstrated under conditions and upon animals where the possibility of the reflective consideration of the problem by the subject is out of the question.
2. The retention of one habit may be quite unaffected by the mastery of a second habit whose learning, however, was interfered with by the former.
3. It has been found that the result secured varies accordingly as time, errors or trials is used as the criterion of learning. (Distance records have not been taken.[2])
4. The question of the effect upon the second habit of varying amounts of practise on the first habit has been raised.
5. The problem of the graphic representation of the locus of the positive or negative transfer has been carried farther than

---

[2] Which of these criteria is the best is not adequately considered in the above papers, although the question cannot be put aside as irrelevant. The use of errors has always been severely criticised. The number of trials as a criterion of the amount of effort put forth may also be a serious mistake inasmuch as a trial is an arbitrary division made on the basis of one performance of the final correct response, such as entering the food-box. The problem of the adequate criteria of learning was not the problem of the above papers and is not the problem of the present one, and yet it is involved in all studies of learning.

in the incidental studies made prior to those that we have summarized.

6. Evidences of retroaction have been found in maze studies by some investigators but not by others. No evidences have been found with auditory habits.

7. Humans and rats have given essentially the same results in transfer tests in the maze. A lack of correlation for both classes of subjects has been found between learning a maze and relearning after a thirty-day interval during which practise has been had upon various activities by certain groups and rest has been given other groups.

PROBLEMS OF THE PRESENT STUDY

The initial purpose of the present study was to plot a curve for habit interference. Pearce (2) had shown that the formation of one visual habit may interfere greatly with the formation of the opposite habit. Consequently if the number of trials required to learn the second habit is taken as the first ordinate value on the curve, then subsequent ordinate values will indicate the number of trials required to master the second habit when the first habit has been partially learned through the practise involved in 20, 30, 100 or more trials (represented on the abscissa). No noteworthy success has attended this problem although it has been possible to indicate three points on such a curve. The points chosen were the two terminal ones and that for 100 trials on habit no. 1.

A second main problem was formulated shortly after experimental work had begun. This was to secure data by correlation methods from various types of interfering habits indicating the relationship between the ability displayed in mastering one habit and the ability displayed in breaking that habit by forming an antagonistic one.

The data that follow throw light also upon certain other aspects of habit interference, noteworthy among which is the locus of the interference or transfer effects as shown by the curves of learning.

INTERFERENCE BETWEEN VISUAL HABITS

Two chief problems were attacked through the study of visual habits as indicated in the preceding section. One of these concerned the relationship between the ability to acquire a habit and the ability to break that habit by acquiring an antagonistic response to the same stimulus. The other problem concerned the relationship between varying amounts of training upon habit no. 1 and the number of trials required for the mastery of habit no. 2. It is this latter problem that should furnish the data for a curve of habit interference.

The apparatus used for both problems was a T-shaped discrimination box of the same design as that employed by Hunter, Yarbrough and Pearce. The only essential difference between the present experimental conditions and those used by Pearce lay in the nature of the stimuli employed. She used light intensities that were physically different but physiologically equivalent, while I have used stimuli identical physically and have required the animals to build up opposite responses to the same stimulus.

The rats employed as subjects were first fed on the experiment table for three days and then for each of the next two days were given one trial through the box without light or punishment. The regular trials began on the sixth day using punishment and reward. Ten trials were given daily. For habit no. 1, the animals were required to run through the right side of the box when the light was presented and through the left side for darkness. Training was continued until the average for two successive days was 95 per cent correct. A control was then introduced using neither light nor punishment in order to be certain that light was the essential cue for the response. The formation of habit no. 2 was then begun. In this practise, the directions of the responses were reversed, i.e., the rats were forced through the left side of the box for the light and through the right side in response to the absence of light. The only records kept were of the correctness or incorrectness of the response and of the number of trials required. The times involved were regarded as too short to allow of significant measure. (Time was taken, however, in the unit maze and will be treated in the section below dealing with that topic.)

The method just described gave data on such "total" interference as might be present between the complete mastery of the one visual habit and the subsequent complete mastery of the second habit. 16 rats were used, each thirty days old when training began.

Figure 1 presents the distributions for both habits in terms of total trials required prior to completed learning. The average for the first habit is 286 trs., P. E. 68.12, and for the second habit, 603 trs., P. E. 103.1. The difference between the averages is 317 trs., while the P. E. of the difference is 33.52 trs., or about one-tenth. The foot-rule correlation between the ranks in the two habits is 0.13 ± 0.107, which transformed by table into the Pearson r is 0.226.

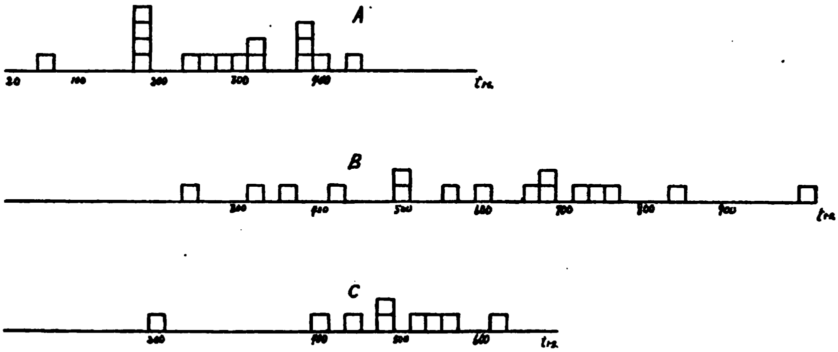


FIG. 1. *A*, the distribution for visual habit no. 1 where the subjects are untrained. *B*, the distribution for visual habit no. 2 after the subjects have mastered habit no. 1. *C*, the distribution for habit no. 2 after the subjects have had 100 trs. on habit no. 1. Each square represents one subject.

On the basis of these facts we can say that the learning of habit no. 1 has interfered markedly with the learning of habit no. 2. In this particular case the animals required on the average twice as many trials to break the habit (i.e., to form habit no. 2, and I assume that habits can only be "broken" through the factors of disuse and the active competition of other habits) as they did to form it. The data fail to show any significant relationship between the individual rat's performance in the two habits. There is furthermore a greater variability of performance in the second than in the first habit (see fig. 3 also).

The graphs of figure 2 show the progress of the two habits when stated in terms of the average percentage of correct responses in each tenth of total learning. (I assume that this method of plotting learning curves, first devised by Vincent, is sufficiently familiar that no extensive words of explanation are necessary. Certain comments upon the method will be found below, page 49.) The striking feature about the curves is that the interference is found in the first half of the curve for habit no. 2, after which the curves progress together. This is confirmatory of the previous findings of Hunter, Yarbrough and Pearce working under similar conditions. The explanation of the peculiarity may well lie in the nature of interference between habits of the present type. It does not lie in the fact that most of the learning in each habit has been accomplished during the first half of the total learning process. This we shall find to be true in the maze habits to be described later. Here, however, the curve for habit no. 1 stands at 52 per cent correct out of all responses made during the fifth tenth of learning as opposed to 48 per cent in the first tenth. Habit no. 2 stands at 51 per cent in the fifth tenth, but has risen steadily from 24 per cent in the first tenth. Each habit reaches approximately the 75 per cent level before the final trials at completed learning. The second habit, therefore, not only meets the first habit at its mid-points, but also rises much more rapidly during the first half of its formation. This is also true in Pearce's curve, and one of the two presented by Hunter and Yarbrough is almost a facsimile copy of the present one. The present curve is more reliable than either of the others because of the larger number of subjects involved.

It will be recalled from our historical summary, that Webb found the positive transfer effect located in the first five trials of the second habit, or, stated otherwise, that the second habit began at the approximate level attained by the first habit on the fifth trial. There is no doubt that Webb's curves show this, but there is question whether his curves can afford a basis for a conclusion of this character. We have already pointed out that a trial is an arbitrary unit having little direct relationship to the amount of effort expended in the learning. One trial for one subject may represent one-tenth of learning while for another subject one trial may represent one-half of the total learning process, and yet the two subjects may spend an equal amount of

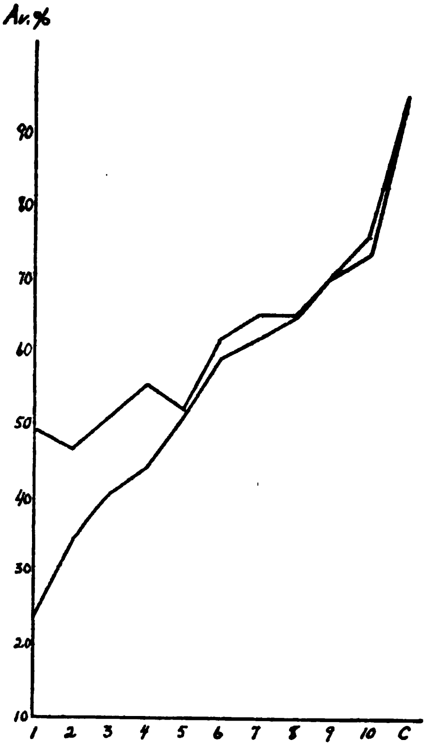


FIG. 2. THE UPPER CURVE IS FOR VISUAL HABIT NO. 1 AND THE LOWER CURVE FOR VISUAL HABIT NO. 2

The curves represent the average percentage of correct trials in each one-tenth of learning. The final value, marked *C*, indicates the average percentage at completed learning. Special attention should be given the coincidence of the two curves beginning at their mid-points.

total time and run equal distances in securing mastery of the problem. Webb's conclusion bears upon the part of the learning process in which transfer effects are found; but since his curves are not representative, his conclusion cannot be accepted.

In following out the second problem of this section of the study, I sought to secure data by which to construct a curve for habit interference in terms of the effects of various amounts of training with habit no. 1 upon the amount of training necessary to break this response by forming habit no. 2. Only three points on this curve have been (approximately) determined, viz., those for zero trials, 100 trials, and total interference.

Nine 30 day old rats were trained upon habit no. 1 by the method above described for ten days, i.e., for 100 trials. At the close of this period, they were put in training upon habit no 2 and continued there until this habit was perfected. An average of 475 trs., σ 112, was required for the mastery of habit no. 2. It has been stated above that when habit no. 1 was completely learned, an average of 603 trs., σ 192, was required by 16 rats for the mastery of habit no. 2. I have assumed that habit no. 2 is of the same grade of difficulty as habit no. 1, for untrained animals, and have therefore taken the number of trials required for the complete learning of habit no. 1 as the number of trials that would be required for the mastery of the second habit—in this case 286 trs., σ 101, for 16 animals.

Figure 3 shows the curve drawn through the three points as slightly convex to the base line and rising from 286 trials for initial learning, through 475 trials for 100 trial interference, to 600 trials at the point of total interference. The ranges of the sigmas are also indicated. It is further to be noted that figs. 2 and 3 are in general agreement. Figure 2 indicates that the major portion of the interference occurs in the first half of the learning. Figure 3 shows that if habit no. 1 is approximately one-half learned (100 trs. out of 286 trs.) that the amount of interference is approximately one-half the possible interference (475 trs. minus 286 trs. giving 189 trs. *vs.* the 317 secured by subtracting 286 from 603). I am willing to infer from the general direction of the curve, the slight amount of curvature, the progressive magnitude of the variabilities, and the number of cases involved, that future experimentation will not change the essential results. The great variabilities in performance in these habits will make it difficult to use them for further interpolations on the curve. Certain data secured with these habits using 10 tr. and 50 tr. interference, also lead me to think either that "the rat in this problem" is too unreliable for the accurate determination of other points on the curve or that the processes involved in habit formation in general are so complex as to render

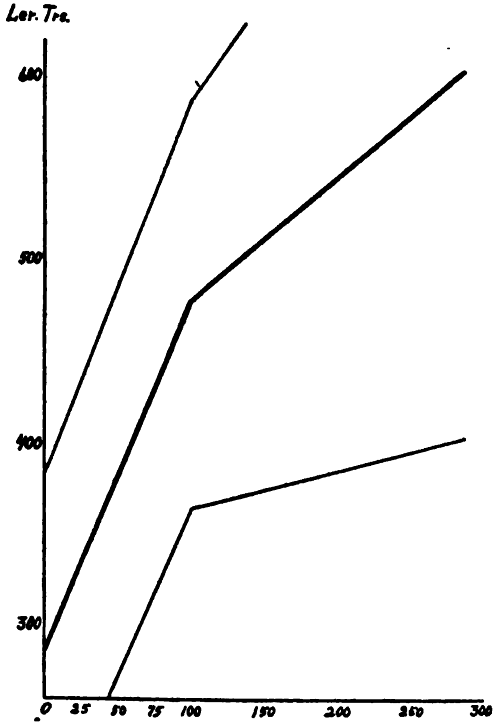


FIG. 3. THE CURVE OF HABIT INTERFERENCE

The values on the ordinate indicate the number of trials given on habit no. 2 in order to secure its mastery after the number of trials on habit no. 1 indicated by the values on the abscissa. The fainter lines on either side of the main graph indicate the magnitudes of the sigmas at the three points determined.

impracticable the accurate determination of many points on such a curve.[3]

INTERFERENCE BETWEEN UNIT MAZE HABITS

The T-shaped discrimination box was also used in this problem. The animals (25 rats, untrained and 30 days old) were run through the apparatus twice daily for four days prior to the regular experiments, using the following series of presentations: *rl, lr, rl, lr.* This preliminary training was given partly to familiarize the subjects with the experimental situation and partly to give the right and left turns through the box an equal potency. Neither punishment nor any external light or sound stimulus was employed either during the preliminary days or during the regular experiment. Habit no. 1 consisted in the ability to run through the left side of the box when the rat was inserted at the entrance. This involved the avoidance of a single cul-de-sac composed of the right side of the box. Habit no. 2 consisted in the ability to run through the right side of the box in order to secure the food which was given between each trial during the formation of each habit. After the four days of initial training, the rats were started on habit no. 1. This habit was considered established when the animal ran through the left side of the box correctly (i.e., without retracing or entering the right side) 19 times out of 20 (10 trials were given daily). These twenty trials need not be on two successive days, but might cover parts of three successive days. As soon as the standard of mastery was reached, the animal was rested for twenty-four hours and then started upon habit no. 2 where the standard of learning was the same as before. A fifteen seconds interval was allowed between the animal's exit and its re-insertion for the following trial. Record was kept of: the correctness or incorrectness of the trial; the total number of trials required for mastery; and the total time for each trial. Inasmuch as the true path was only 48 inches long, the time for each trial was relatively short. The discussion below will indicate the general value of these time records. In counting errors, I have used the method employed in studies of sensory discrimination rather than the customary maze method, i.e., the trial as a whole was counted right or wrong without recording the several mistakes that might be made within that unit.

---

[3] The situation here is at variance with that described by Wiltbank for the maze and summarized above in our historical section. Wiltbank's data show an effect in the second habit of as little as 2 trials on the first habit.

Figure 4 gives the distribution tables for the two habits in terms of trials and total time consumed prior to mastery. For habit no. 1, the average number of trials is 34.28, σ 25.5, and the average number of seconds required for total learning is 196.7 seconds, σ 108.4. For habit no. 2, the average number of trials is 45.32, σ 20.9, and the average number of seconds is 183.89, σ 70.8. The foot-rule correlation for time is − 0.04 ±0.08, and for trials is −0.075 ± 0.08. The P. E. of the difference of the average trials required is 4.13 as opposed to the arithmetical difference of 11.04 trs., and the difference between the two averages is therefore fairly significant. A consideration of the coefficients of correlation indicates that no relationship has been found between the performances in the two habits. Whether this is due to the nature of the rat, the problem, or the experimental control, I am at present unable to say. The results show an interference effect between trials required, but show a practical equality in the amounts of time. So far as total trials are concerned, habit no. 2 is less than a new habit. So far as total time is concerned, habit no. 2 is acquired as a new habit.

These statements, confirmed also by the previous work of Hunter, Yarbrough and Pearce, call legitimately for explanatory comments on the nature of a "new" habit. In addition to the work already before us, it is necessary to have in mind the fundamental study by Shepard and Breed (8) on "Maturation and Use in Instinct." These psychologists have shown in the case of the pecking behavior in the chick that the curve of acquisition is the product of the two factors of practise and the inherent processes of growth. It is probable that most instinctive forms of behavior appear in a similar fashion. However, in the case of the great majority of acquisitions whose curves are studied the processes of maturation concerned have already been completed.

These forms of behavior appear under the influence of old acquisitions as well as of the environing experimental conditions. In spite of this, for practical purposes, we say that a discrimination habit, e.g., set up in an "untrained" rat is a new habit and think of the rat thereafter as unsuited to the best scientific study of other habits (unless habit relationships are our topic of study). This position is supported by the habit interrelationships indicated through studies of the type which we have reviewed.

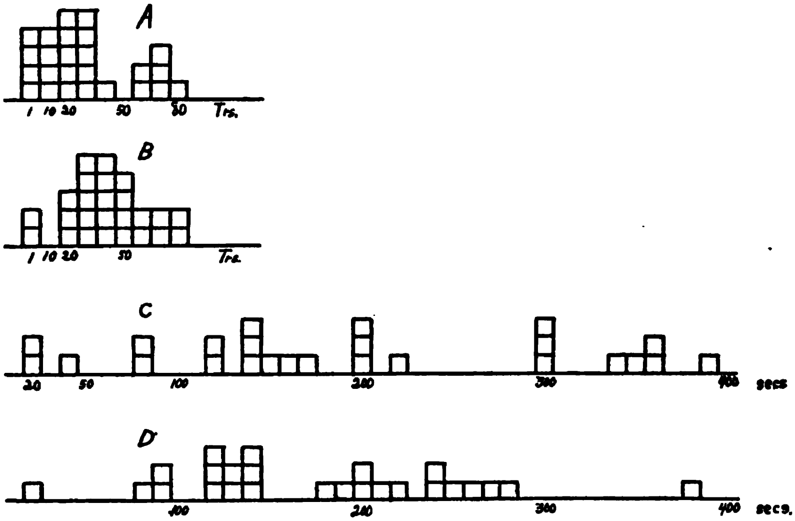


FIG. 4. DISTRIBUTIONS FOR THE UNIT MAZE HABIT

A and *B* are the distributions for trials preceding mastery for habits nos. 1 and 2 respectively. *C* and *D* are the time distributions for the two habits. Each square represents a subject.

We should not, however, be blinded to the existence of quite highly independent habits. Studies in human psychology on amnesias, repressions, and dissociations in general have indicated this. The work of Bair, Muensterberg, Hunter and Yarbrough referred to in the introduction to the present paper show independent habits in the field of skill. The work by the latter investigators and that presented in the present section lead to the statement that a habit is to be judged "new" on the basis of a comparison of its curve of acquisition with the standard curves for that habit. If the curves are essentially identical in points of origin and termination and in form, the one may be said to represent the growth of a new habit no matter how much training the animal may have had. In the present case, the standard curve is that for habit no. 1. Habit no. 2 is to be judged as new, as less than new, or as partially acquired in terms of the three attributes above stated, of which form is the most uncertain.

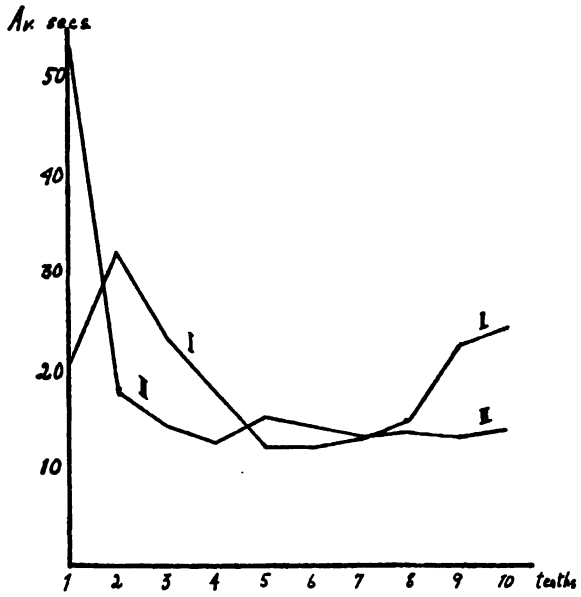


Fig. 5. Curves of Learning for the Unit Maze

The ordinate values represent the average number of seconds required in each tenth of learning. I, habit no. 1. II, habit no. 2.

As we pass from positive transfer where the curve in question is above the standard to negative transfer where it lies below the standard, a point will be reached where the two curves coincide. There is no pragmatic difference between a new habit and one in which interferences and transfers give the standard curve. Theoretically there is no such thing as a new habit. Each arises under the influence of some or all of the existing behavior possibilities acting through facilitations and inhibitions in the nervous system. In practise, however, a new habit would be identified by the criteria above described.

Figure 5 presents the curves of learning for the two habits formed in the unit maze. The graphs represent the average number of seconds of total time spent in each tenth of total learning. Those of figure 6 show the average percentage of the total time required for learning which occurred in each tenth. The curves in each case interlace to an extent which makes conclusions as to essential differences uncertain. It would seem safe, however, to say that habit interference has brought a great

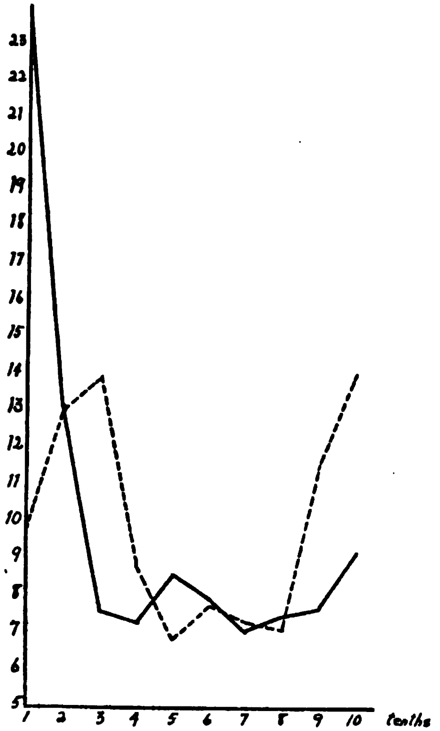


FIG. 6. CURVES OF LEARNING FOR THE UNIT MAZE

These curves represent the percentage of total time that the average rat spent in each tenth of learning. The solid line is for habit no. 1.

increase in the amount of time spent in the first tenth of habit no. 2. (Additional comments will be found below, p. 51.)

HABIT INTERFERENCE IN THE CIRCULAR MAZE

The problems attacked by means of the circular maze were still those of: (1) the relationship between the ability to form a given habit and the ability to break that habit by forming its opposite; and (2) the locus of the interference effects as shown in the curves of learning. A simple circular maze with camera lucida attachment was used. The first habit consisted in the mastery of the maze as shown in figure 7. Two trials per day were given, and records were taken of total time, stationary time and distance. Learning was counted complete when four trials in succession were made without error. Habit no. 2 consisted in the mastery of a maze in which the food box and the alley openings on the side of the food box were shifted 180° from the position shown in fig. 7. The turns in maze no. 2 were, therefore, *lrlr* as opposed to the *rlrl* order in maze no. 1 (shown in fig.7).

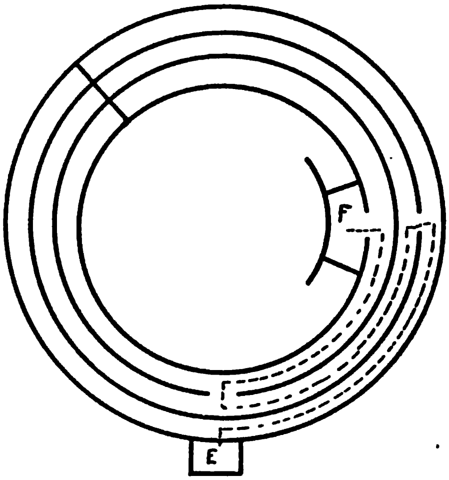


FIG. 7. GROUND PLAN OF THE CIRCULAR MAZE

E is the entrance and *F* is the food box. The dotted line indicates the true pathway.

The subjects were started on maze no. 2 approximately twenty-four hours after maze no. 1 was mastered.

Thirty-six thirty-day old untrained rats were used. Time records only were taken for 11 of these. For the remaining 25, both time and distance were recorded. Ten minutes was the maximum time allowed for the first trial in the case of the set of 11 animals. The remaining 25 were kept in the maze until they had completed the first trial.[4] One minute intermission was given between trials. For four days prior to the regular tests, each animal was given one run per day down a 24 foot straight-away to his food.

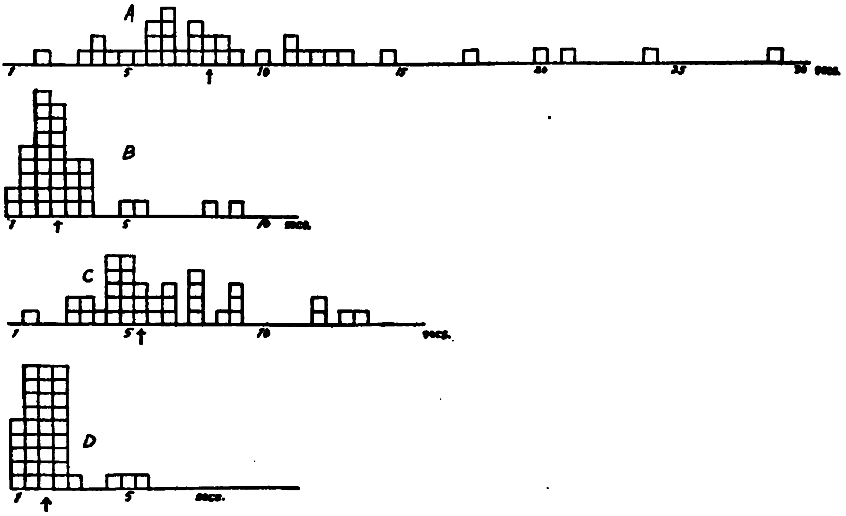


FIG. 8. DISTRIBUTIONS FOR TOTAL TIME (*A* AND *B*) AND FOR NET TIME (*C* AND *D*) IN THE TWO HABITS WITH THE CIRCULAR MAZE

The arrows indicate the medians. The values on the base lines are in hundreds.

The distributions secured for the two habits are shown in figures 8, 9 and 10. A comparison of the median values, indicated by arrows, reveals a positive transfer with all criteria. This is in harmony with the work by Webb and Wiltbank. A greater variability is apparent in the first than in the second habit (a condition also true in the unit maze), which is the reverse of the situation found in visual habits. It is possible that the difference is essential and that it is related to the slow rise of the latter habits.

---

[4] Of the eleven rats upon whom a time limit was set, 8 had unfinished trials. These unfinished trials for a given rat were added to the first succeeding trial which was completed, and the whole treated as one trial.

The Pearson correlation between total trials required for habit no. 1 and total trials required for habit no. 2, using the record for 36 animals, is 0.31 ± 0.10. For total time, the foot-rule coefficient is 0.126 ± 0.07. Using the 25 rats for whom alone distance records were available, the foot-rule correlation of total distances traversed during learning is – 0.02 ± 0.08 and for net time is 0.36 ± 0.08. The correlations for net time and trials are higher than the coefficients previously recorded in this paper for visual and unit maze habits. However, even these correlations are lower than I should have anticipated. If the rat in the maze or discrimination box, under the current experimental conditions, gives reliable data on learning, one would expect that the animals learning the first habit most readily would also learn the second habit most readily. This proves to be the case only to a slight degree, if at all. There remains the possibility, not covered by our experimental data, that the animal learning most readily also retained most readily and hence did poorly on the second habit. However, if this had been the case to any great degree, significant negative correlations should have been in evidence. Additional

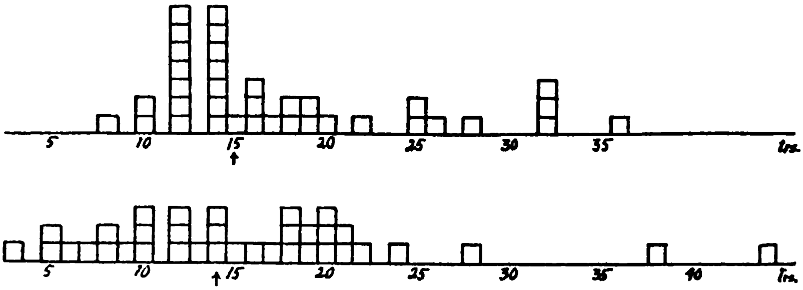


FIG. 9. DISTRIBUTIONS FOR TOTAL TRIALS REQUIRED PRIOR TO MASTERY FOR THE TWO HABITS IN THE CIRCULAR MAZE

The arrows indicate the medians

evidence against the effects of retention come from the fact that Webb found an absence of correlation between learning and relearning the same habit after an interval of thirty days.

Figures 11, 12 and 13 show learning curves for the two habits under consideration. Each of the curves is constructed in terms of tenths of the total learning process. This method of construction devised by Vincent is of very great merit where a composite curve is to be studied. Daily fluctuations, it is true, are not shown, but that is chiefly the function of an individual's curve. The degree of smoothness can be controlled, in the Vincent curve, by the choice of unit, a curve in tenths being smoother than one in twentieths, etc. In the Vincent curve, the entire curve is based upon the total number of subjects used while in the customary curve the latter part may be based upon a single animal, the other subjects having dropped out at various preceding points. Conclusions concerning the forms of the curve, if based upon more than one animal, are unsafe unless the entire subject group is represented throughout the curve. The Vincent curve has the additional advantage that any accidental disturbances will have their effects distributed through various parts of the curve in a way less calculated to affect its essential form.

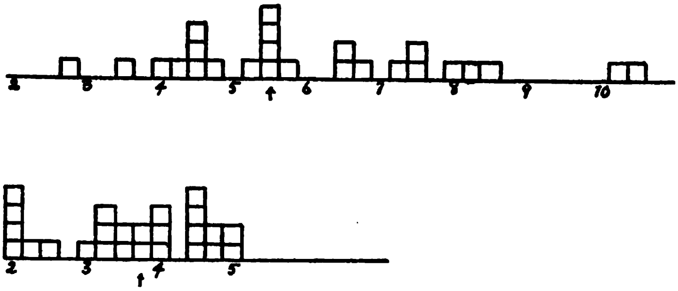


FIG. 10. DISTRIBUTIONS FOR TOTAL DISTANCES TRAVERSED PRIOR TO COMPLETED LEARNING IN THE TWO HABITS OF THE CIRCULAR MAZE

The arrows indicate the medians. The abscissa values are arbitrary units

Turning now to the curves before us, figure 11 shows the average amount of distance run in each tenth of total learning for the two habits. A marked transfer effect is to be noted.

This is also true in figure 12 which shows the average total time consumed in each tenth. Figure 13 is also based upon total time, but in this case the ordinate values represent the average percentages of total learning time consumed in each tenth. The curves therefore represent the average precentage of total work which lay within each tenth. A comparison of figures 12 and 13 reveals that, although habit no. 2 required the expenditure of much less energy in each tenth, the percentage of work in each tenth of learning is the same as for habit no. 1.

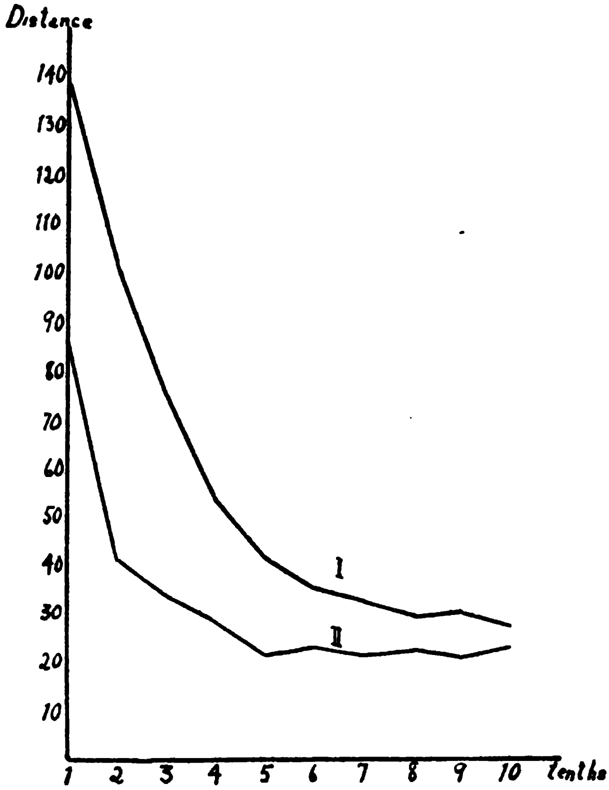


FIG. 11. LEARNING CURVES FOR DISTANCE FOR THE CIRCULAR MAZE

The curves represent the average total distance run in each tenth of the learning period. I, habit no. 1. II, habit no. 2. The ordinate values are arbitrary units.

This is in marked contrast with the curves shown for the unit maze where the first tenth of learning for the second habit included over 50 per cent of the work done on that habit, as opposed to 20 per cent for habit no. 1. A comparison of the curves also suggests that the distribution of work throughout the learning period will depend upon the type of problem used and upon various other factors other than the mere fact of habit formation.

The curves of the present paper, including those of the succeeding section, show clearly the portion of the learning period during which the great portion of the learning is accomplished. An inspection of the graphs of figures 2, 5, 11, 12 and 13 reveals the fact that there is practically no indication of improvement after the mid-point in the learning period. The criterion of mastery in maze habits and in sensory discrimination problems, as well as in most other problems of animal behavior, is one of errors committed. The progress towards mastery, however, is recorded in terms of time and distance as well as of errors. Our curves show that the variations in time and distance records are very slight, beginning at a point around the fourth, fifth or sixth tenth of learning. Most curves heretofore presented in the literature

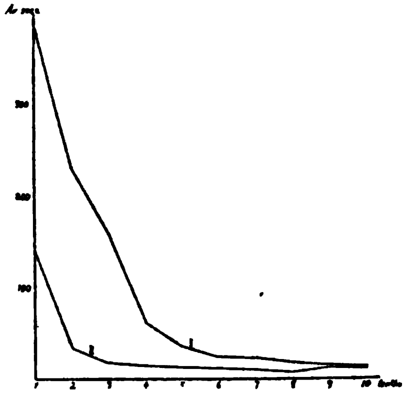


FIG. 12. LEARNING CURVES FOR TOTAL TIME IN THE CIRCULAR MAZE

The ordinate values represent the average number of seconds of total time consumed in each tenth of the learning process. I, habit no. 1. II, habit no. 2.

show a rapid initial drop followed by a gradual approximation to the final level. Their non-representative character, however, when compared with the Vincent curve, makes any generalization concerning parts of the learning process impracticable.

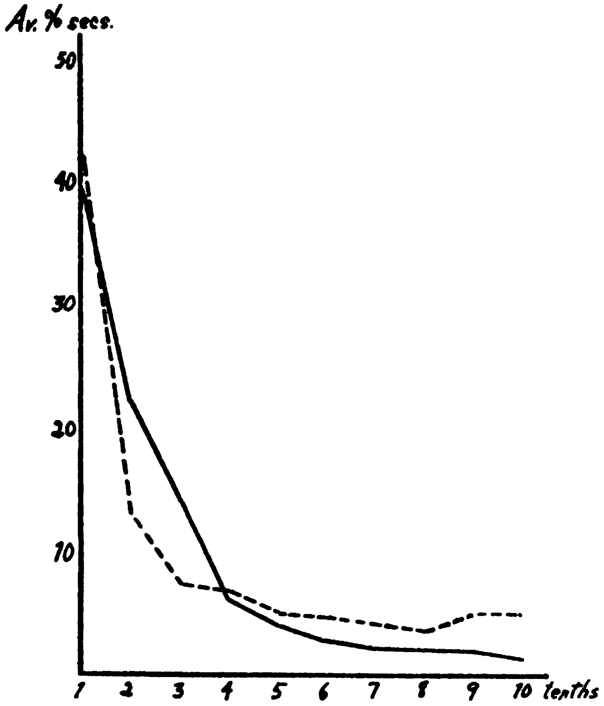


FIG. 13. CURVES SHOWING THE PERCENTAGE OF TOTAL TIME FOR THE AVERAGE RAT, OCCURRING IN EACH TENTH OF THE LEARNING PERIOD

The dotted curve is for habit no. 2; the solid curve, for habit no. 1

The curves of figure 2 and those in the papers by Hunter, Yarbrough and Pearce are error curves. In contrast to the time and distance curves, they show a significant improvement in the latter half of the learning period. In all cases the mid-regions of the curves possess particular significance, either as the point beyond which little improvement occurs or as the point on either side of which the interference effects are found.

INTERFERENCE BETWEEN MAZE HABITS WITH HUMAN SUBJECTS

Thirty-one human subjects were tested on the pencil maze shown in figure 14. The turns here as in the circular maze are alternately right and left. Habit no. 1 consisted in learning the maze as drawn in the figure. Habit no. 2 required the mastery of the reverse of this maze. (Secured by rotating the maze 180 degree with reference to the subject and by having the subject trace from the former exit to the former entrance.) Forty-five seconds elapsed between each trial in both problems. The two habits were established in one continuous sitting, with a fifteen minute rest period between the two. The subjects were instructed as follows: "Now that you are blind-folded, I shall place a pencil in your hand and then guide you (so) until the pencil point is within the groove of the maze. You are to find the shortest way out of this groove by moving until I say 'out.' Do not lift your pencil up so that it slips out of the groove. Work for an early mastery of the problem." Between trials the subject was instructed to think of other topics and was usually engaged in a general conversation. Five perfect runs in succession were required for mastery. Record was kept of the total time for each trial and of the total number of trials.

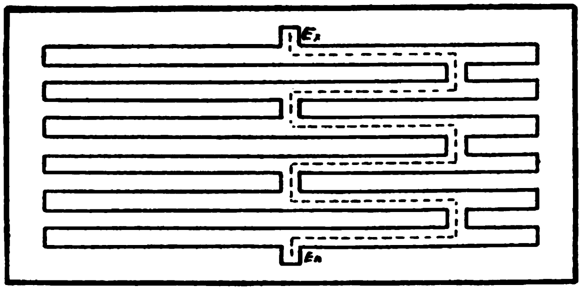


FIG. 14. GROUND PLAN OF THE PENCIL MAZE

En, entrance. *Ex*, exit

The maze was constructed with grooves ¼ inch wide. The pencil point occupied probably about 1/16 inch. It was thus impossible to touch both sides of the maze without making fairly large movements (subjectively estimated).

Of the subjects, 25 were elementary laboratory students in psychology, 4 were advanced students, and 2 were instructors. Only the last six were familiar with maze problems in general. All subjects testified freely to an ignorance of the maze with which they were tested. The elementary students were cautioned against coaching, and no evidence of such methods was found.

Figures 15 and 16 give the distributions of time and trials for each habit. The arrows indicate the location of the median values. Inspection reveals a great amount of transfer from the first to the second habit. The foot-rule correlation between total time in the two habits is 0.64 ± 0.07. The same coefficient for total trials is 0.68 ± 0.07. Translating these values by table into the Pearson r gives in each case a coefficient above 0.80.

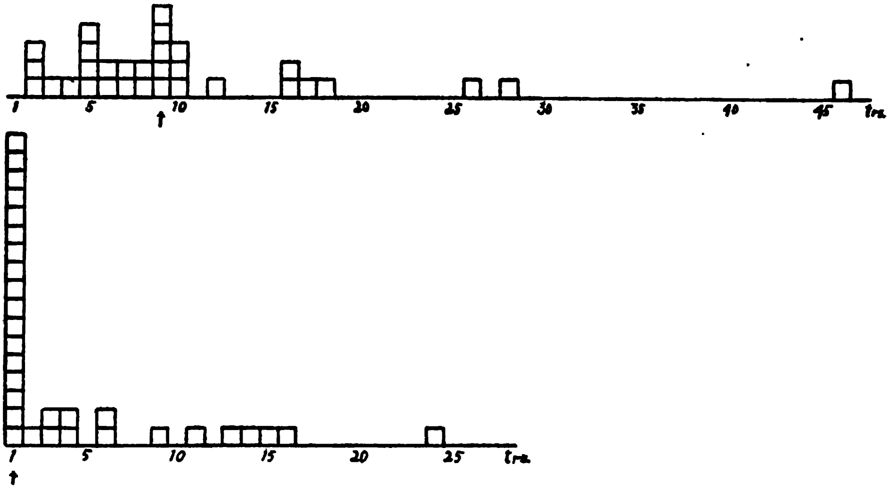


FIG. 15. DISTRIBUTIONS IN TERMS OF TRIALS REQUIRED FOR MASTERING THE TWO HABITS IN THE PENCIL MAZE

The arrows indicate the median values

A comparison of these correlation values with those secured from the rat reveals one of the most significant points brought to light by the present investigation. Working with visual habits and two complexities of the maze, using rats for subjects there is a very low degree of relationship, if any, between the abilities manifested in forming a habit and in breaking that habit by forming another. As opposed to this, a high degree of relationship is found in human subjects between the ability to form a simple maze habit and the ability to break it by forming another maze habit. In each case standard methods of experimentation have been employed.

In our historical section, we pointed out as extremely significant the data found by Webb on the correlation of abilities displayed in learning a response and in relearning the same response after a thirty-day interval. In Webb's tests the different groups of subjects received various treatments during the interval. One group on each maze enjoyed a rest from experimentation during the interval. The other group on each maze was trained upon some other maze during the interval. (No data are given showing the amount of progress made in the formation of habits during the thirty-day interval.) The coefficients found for the three criteria of trials, errors, and time for rats vary from -0.57 to 0.85. Although three groups show a consistent positive correlation on all three criteria, the data as a whole suggest apparently either that there is no relationship present (which is Webb's conclusion) or that only certain mazes will

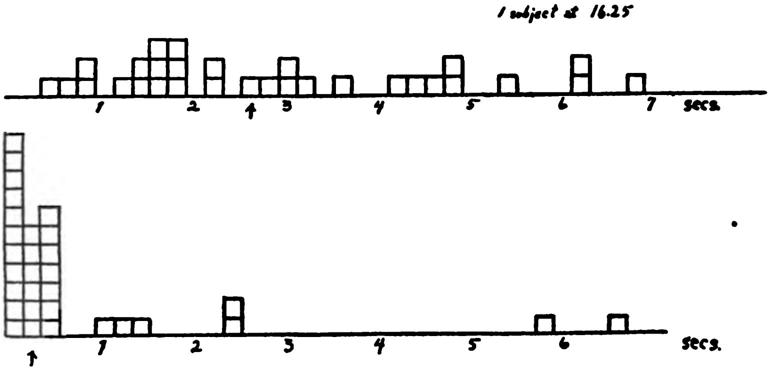


FIG. 16. DISTRIBUTIONS IN TERMS OF TOTAL SECONDS REQUIRED FOR MASTERING THE TWO HABITS IN THE PENCIL MAZE

The abscissa values indicate hundreds. The arrows indicate the median values.

show this relationship. There are no published facts at present to indicate which answer is the true one. It is certainly quite possible that chance factors may enter into certain mazes to such a degree as to render them unfit for testing learning, if consistent results are to be secured. *It must be borne in mind that the mere*

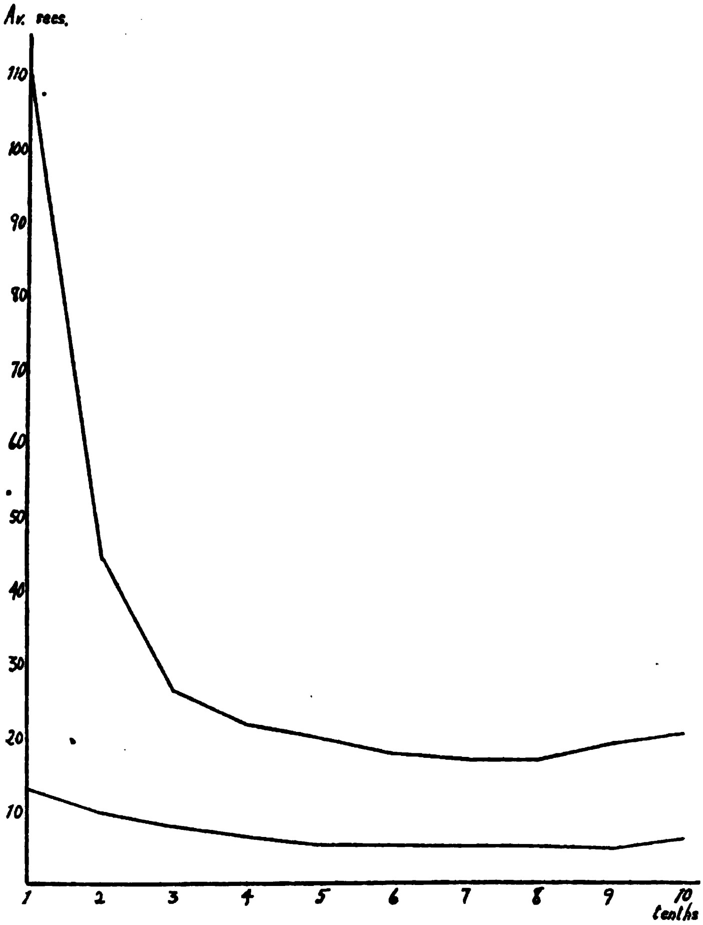


FIG. 17. LEARNING CURVES FOR THE TWO PENCIL MAZE HABITS IN TERMS OF THE AVERAGE TOTAL TIME IN SECONDS PER TENTH OF TOTAL LEARNING

The upper curve is for habit no. 1

fact that an animal forms a habit under certain experimental conditions is in no sense evidence that the records of that learning will ever reveal that the animal had the ability to make a consistent performance. For human subjects, Webb's results show correlation from −0.60 to 0.70, but with no significant and consistent correlations for the several mazes.

Our own correlations were secured under different experimental conditions, where the one maze habit was replaced immediately by its opposite. We found no correlation between the two performances for rats, but a fairly close relationship for humans. Inasmuch as Webb had but from 5 to 6 human subjects while we used 31, our results would seem the more trustworthy.

It appears to me that the most probable explanation of the differences found by correlation in the present section of this paper will prove to be one of the following: (1) *A better and more uniform control of experimental conditions is possible for human subjects than for rats.* Or (2), *the rat is intrinsically more unstable than human adults, being so susceptible to various factors that the same capacity reveals itself but poorly and inconsistently through a series of habits.* Either explanation is serious for animal psychology if, and so far as, studies of habit formation in the rat are supposed to throw light upon the essential nature of habit formation in man. Either explanation is of great importance so far as the problem of animal psychology is that of indicating essential differences between animal groups.[5]

Figure 17 gives the learning curves for the two habits in terms of the average total time per tenth of the learning period. Two features stand out: (1) the great amount of transfer evident throughout the curve for habit no. 2; and (2) the absence of essential change in the last six tenths of the graphs. The transfer revealed is greater than that shown in any of the earlier curves of the present paper, the first tenth of habit no. 2 requiring even less time than the last tenth of habit no. 2.

---

[5] Extensive experiments bearing upon the topics of this paragraph have been in progress in this laboratory for several years (conducted by D. G. Paterson, Oakland Maupin, William T. Heron and myself) and should see publication in the near future.

SUMMARY

On page 33 an outline was made of the present status of the problem of habit interference and habit transfer in animals. The work of the present paper may be put in relationship to the material there summarized as follows:

1. Negative transfer, or habit interference, has again been demonstrated between opposite visual habits.
2. When the learning is represented in the form of a Vincent curve and the two habits are compared, interference is shown to have its locus in the first one-half of learning.
3. Positive transfer appears between two opposite maze habits when either the total times, distances or trials are considered. A comparison of the last of the first habit and the first portion of the second habit reveals interference effects. The learning curves for time and distance show almost no improvement after the mid-point of the learning process.
4. Argument is given in favor of the use of the Vincent curve where a composite curve representative of the learning process is to be presented.
5. A curve for habit interference in visual habits has been drawn through the points of zero, 100 trial and total interference. (A smaller number of trials than 100 ln the first visual habit, viz., 10 and 50 trials, failed to show any effect on the second habit.)
6. The indications are that there is a greater variability in performance in a second visual discrimination habit than in a first one. The situation seems to be reversed with maze habits.
7. We have found no significant correlation in rats between the learning of one habit and the breaking of that habit through the mastery of its opposite. Visual discrimination habits and two complexities of maze habits were used. Human subjects in a pencil maze gave a high correlation between forming one habit and replacing that habit with its opposite.

REFERENCES

(1) **Hunter**, W. S., and **Yarbrough**, Jos. U.: The interference of auditory habits in the white rat. Jour. Animal Behav., 1917, vii, 49–65.

(2) **Pearce**, **Binnie** D.: A note on the interference of visual habits in the white rat. Jour. Animal Behav., 1917, vii, 169–177.

(3) **Webb**, **Louie** W.: Transfer of training and retroaction. A comparative study. Psych. Rev. Mons., 1917, xxiv, no. 3.

(4) **Wylie**, **Harry** H.: An experimental study of transfer of response in the white rat. Behav. Mons., 1919, iii, no. 5.

(5) **Hunter**, W. S.: Some notes on the auditory sensitivity of the white rat. Psychobiology, 1918, i, 339–351.

(6) **Brockbank**, **Thomas** W.: Redintegration in the albino rat. A study in retention. Behav. Mons., 1919, iv, no. 2.

(7) **Wiltbank**, **Rutledge** T.: Transfer of training in white rats upon various series of mazes. Behav. Mons., 1919, iv, no. 1.

(8) **Shepard**, J. F., and **Breed**, F. S.: Maturation and use in the development of an instinct. Jour. Animal Behav., 1913, iii, 274–285.

COÖRDINATION IN THE STARFISH

II. LOCOMOTION

W. F. HAMILTON

Having described in a previous paper[1] certain experiments on the individual tube feet of starfish, I wish here to present the results of experiments and observations on the mechanism of locomotor coördination in the light of this previous analysis of the reactions of the tube feet.

LITERATURE

It has long been recognized (Romanes and Ewart, 1881; Preyer, 1886) that if one of the tube feet in a starfish is stimulated to retract, or extend, this activity spreads to other tube feet as a wave of extension or retraction. Coördination of the tube feet which involves their orientation in a definite direction, cannot, according to Von Uexküll (1903), be referred to a simple nerve net, as can the spread of simple extension and retraction. Many nerve nets connecting homologous parts of the effectors are needed to explain this type of response. Von Uexküll explained the oscillations of the tube feet and spines of sea urchins on the ground that muscles which are extended, either actively or passively, are more apt to respond, by contracting, to an impulse spreading in the nerve net. Von Uexküll's elaborations of this idea have not always proven acceptable (Mangold, 1909b).

Locomotion away from harsh stimulation and toward food was noticed by the older physiologists (Romanes and Ewart, 1881; Preyer, 1886). The adaptiveness of these responses was pointed out, and while Romanes and Ewart refused to commit themselves as to consciousness or intelligence among echinoderms, Preyer referred these and other adaptive responses to an intelligence equipped with anatomical "centers" in various parts of the ambulacral nervous system. (See also Sterne (1891) and Steiner (1898).)

---

[1] Journal of Comparative Psychology, Vol. I, December, 1921, pp. 473–488.

Norman (1900) and Loeb (1900) dissent very strongly from this view. According to Norman when a ray is harshly stimulated the tube feet thereon are retracted and those of the other rays "determine" the direction of locomotion. According to Loeb the direction is determined "according to the parallelogram of forces" by the unstimulated arms.

Jennings, (1907), however does not see any divergent action such as would be implied by the term parallelogram of forces. There is a "unified impulse" which involves the harmonious action of the tube feet of each ray. This is corroborated by Mangold (1908a), Cole (1913a) and others.

The unified impulse, once formed is very persistent, according to Jennings and must be taken into account in an analysis of the movements of the animals. Cole (1913a) finds that the unified impulse determines the physiological anterior and this physiological anterior persists for some time in the same rays in which it started provided, of course, that laboratory conditions are non-directive. There is however a slow shift of anterior either to the right or left.

Bohn (1908) worked out the physiological factors involved in change in direction of locomotion which was brought about by rotation of the animal, as distinguished from a change which involved a shift of the anterior to other rays.

Jennings (1907) pointed out that the unified impulse might take different directions in different parts of the animal when to do so would be adaptive (in righting, etc.) Mangold (1908a) described this same state of affairs for *Luidia ciliaris* migrating along with one arm bent back double on itself and all the tube feet walking in the same direction—not with regard to the morphology of the arm but with regard to space. This he refers to a "very complex coördination-mechanism" (see fig. 6).

While it is thought by most observers that coördination is conducted solely through the ventral nervous system, Romanes and Ewart (1881) and Cole (1913b) record some slow coöperation between parts on opposite sides of a cut in the nervous system, and Russo (1913) believes that coördination may be absolutely normal in all sorts of echinoderms, with the oral ring removed! Clark (1899) states that the coördinated movements of the tentacles and body muscles in *Synapta* are not destroyed by cutting the nerve ring.

COÖRDINATION IN THE RIGID STARFISH AND IN THE GILLS

The tube feet of "rigid" starfish (see previous paper)[2] since they are not oriented, behave very much as do the dermal branchiae as to contraction and reëxtension after contact stimulation. The wave of contraction proceeds away from the site of the stimulus, gradually diminishing in intensity, and the wave of reëxtension, affecting first the least contracted organs farthest away, spreads back to the point of stimulation. The wave of reëxtension, of course, does not diminish in intensity. There is nothing in this behavior which is not referable to a simple nerve net. (See Parker, 1919.) It is probably not so with oriented coördination.

ORIENTATION IN THE TUBE FEET

The state of orientation, which as has been shown (see previous paper)[3] precedes the step reflex, may arise in several ways. Tube feet may orient themselves directly toward contact stimuli (or luminous stimuli, Plessner, 1913) applied to the dermis. Thus if a starfish is suspended and the body wall at one side of a ray is stimulated by gentle contact, the tube feet nearby will extend toward the point of contact. If the starfish is active this orientation may spread to a greater or less extent over the rest of the tube feet. An increase in the strength of the contact stimulation instead of producing a negative orientation of the tube feet causes their retraction. In other words we have been able to demonstrate receptors in the dermis for a positive but not for a negative orientation of the tube feet.

---

[2] *Loc. cit.*

[3] *Loc. cit*

That such receptors exist in the tube feet themselves as well as in the dermis is suggested by the following. If one of the tube feet of a suspended starfish be brought in contact with a small object, its attachment to that object is usually followed by active bending of the nearby feet toward or parallel to the one stimulated. I have not been able to observe tube feet to bend directly away from the stimulus. Harsh stimulation causes retraction but not negative orientation.

Tube feet will coördinate to passive movements of their fellows. If a long tube foot on a suspended starfish is brought in contact with a pencil point the disk will attach and, if the pencil point is moved so that the tube foot is now pulled out in a new direction, other tube feet will extend themselves, not in the original direction, but rather in the direction to which the tube foot had been passively moved. The response is not invariable, but differs with different physiological states. Coördination to passive movements could also be brought about when the tube foot was twisted (fig. 1) before pulling it over into its new position and the coördination would remain undisturbed when the tube foot was untwisted. The receptors therefore for the direction of orientation are probably situated at the base of the column though stimulation of the disk is a factor in the activity and spread of the coördination.

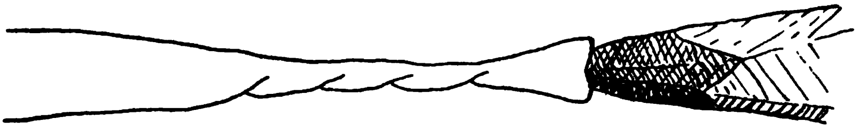


FIG. 1. The tube feet of starfish will orient in the direction to which a tube foot has been passively moved even after it has been twisted as figured.

This experiment furthermore accounts for the previously noted (see earlier paper) orientation of the starfish away from the direction of pull exerted by the spring recorder in determining the pulling ability of the animal. The animal (*Pisaster*) was shown to have pulled steadily for as much as thirty-six hours directly away from the spring recorder. This orientation was not affected by neurotomizing or anaesthetizing the ray attached by the thread to the recorder, and is therefore due to the receptors in the tube feet which are stimulated by the pull of the substrate so as to keep nearby tube feet oriented against the pull.

The tube feet near the ends of the rays of starfish in the active but unoriented physiological state are oriented toward the tips of those rays on which they are situated. The significance of this is shown experimentally by attaching five shell vials large enough to accommodate the ray to five floats and presenting these to the tips of the five rays of an active but unoriented starfish suspended under water (fig. 2). Each ray walked into a vial and in doing so pulled it back toward the disk. When the rays reached the end of the tubes they either migrated further in by bending back at the tips, or reversed and backed partly out. They did not often let go the vials entirely.

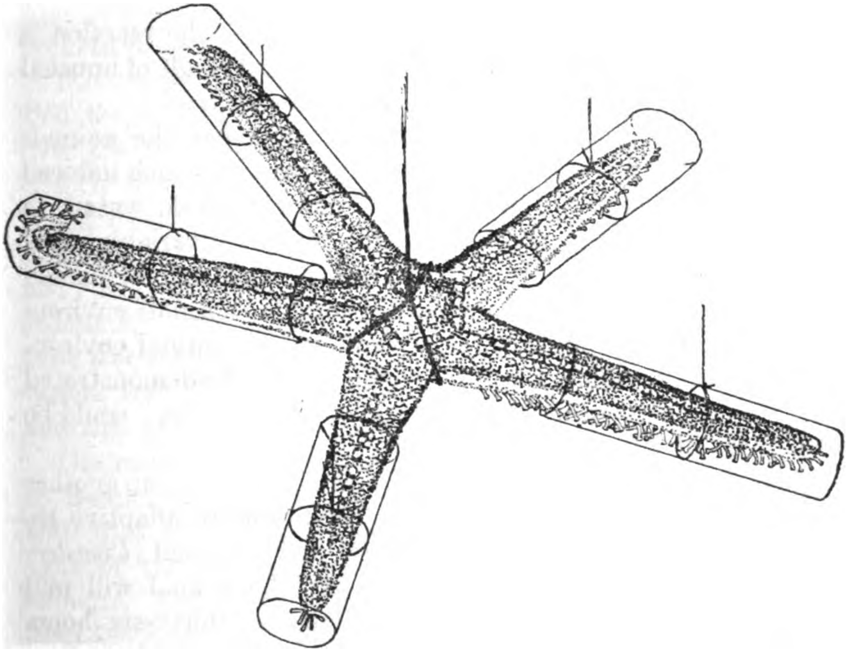


FIG. 2. STARFISH MIGRATING IN FIVE DIFFERENT DIRECTIONS AT ONCE

The animal is suspended under water and five shell vials hanging from separate floats are presented simultaneously to the tips of the rays. If the animal is not oriented each ray walks out into the vial.

Another indication of this tendency may be noted in the fact that in stale water or under the influence of chloroform (Moore

1916) a starfish is very susceptible to a sort of spontaneous autotomy. *Pisaster* seems more susceptible to this reaction if the nervous system has been injured in some part.

As I have observed it, this variety of autotomy is brought about by an exaggerated tendency of the tips of the rays to migrate in their own direction and a failure of this orientation to spread through the pathologically sluggish central part of the ambulacral system. The pulling of the tube feet elongates the rays until they break off at or near the disk. The reaction is probably not adaptive, but merely an accidental result of unusual conditions acting on the Asteroid locomotor system.

This conclusion is founded upon the fact that the animals could not recover from the pathological condition which induced the reaction in the unfavorable environment (stale water) in which the phenomena occurred. The animals invariably died. Recovery might take place if the self-injured animal should (in some manner) be put in a very favorable (normal) environment. On this supposition the advantage in a normal environment of the self-inflicted injuries would have to be demonstrated before we could assume that this type of "self surgery" could be held to be of adaptive significance.

This spontaneous self mutilation differs essentially from another type which may lead, under certain conditions to adaptive results. If one ray of a normal and fairly active animal (*Pisaster*) is tied securely to some stationary object the animal will pull away from this impediment for as much as thirty-six hours (see previous paper).[4] This has been observed to result in freeing the animal by loss of the ray. Regeneration of the lost arm might then be expected to occur; hence the power of autotomy might be said to enable the animal to continue its life.

ORIENTATION OF THE ANIMAL AS A WHOLE

We have laid the foundation in the preceding paragraphs for a description of two methods by which all of the tube feet may become oriented in one direction so that coördinated locomotion may ensue.

---

[4] *Loc. cit.*

In the first place, dermal stimulation or stimulation of the tube feet may give rise to orientation of the tube feet *toward* the locus of the stimulus. In case a sufficient number of the tube feet receive contact stimuli from the substrate, their orientation, resulting in step-reflexes, will spread over the starfish and the animal will locomote toward the stimulation. I have not observed this direct method of orientation to result in a movement of the tube feet directly away from the stimulus, and hence it cannot be used to explain a negative response.

The retraction, however, which results from harsh stimulation does explain the negative response. This retraction spreads over the tube feet of the whole animal and it is last and least effectively expressed in the rays farthest away from the stimulus. Being least affected by the stimulus these tube feet reëxtend first and as a consequence of their situation on rays which point away from the stimulus are themselves oriented away from the stimulus. Here again, then, in case a sufficient number of the tube feet receive contact stimuli from the substrate, their orientation, resulting in step-reflexes, will spread over the starfish and the animal will locomote away from the stimulation.

The negative response of amputated arms, as was first noted by Romanes and Ewart (1881), is not at all regular, as compared with that of the intact animal. This is to be expected in the light of the foregoing analysis since the "rays opposite the stimulus" are not there to unfailingly initiate a migration away from the stimulus. The positive response of the isolated ray as I have observed it, is much more certain than the negative.

The migrating starfish changes its orientation in much the same way as the unoriented animal starts migration. The fact that the change may or may not involve a rotation of the animal as a whole, and the fact that mechanical factors play a part in the change of direction render it rather difficult to recognize the various factors and to follow them in their rather delicately balanced interplay. Aside from mechanical factors, which will be analyzed in connection with the deviation reaction, there are probably no factors operating on the oriented starfish that may not assume a rôle in bringing about that orientation.

It has been shown (Cole, 1913) that a starfish will retain its orientation even after the animal is taken up and held inverted for two minutes. This procedure causes (in *Pisaster* at least) the retraction of the tube feet. From this and the fact that the tube feet are quite retracted after each step we may conclude that the mechanism of orientation and that of extension and retraction are wholly independent of each other. Their only point of contact is that they operate on the same tube foot and that orientation of this organ modifies its direction of extension and changes the retraction to contact stimulation of the disk to a step-reflex.

THE BREAKING UP OF THE ORIENTATION OF THE STARFISH INTO AREAS IN WHICH THE TUBE FEET ARE ORIENTED IN DIFFERENT DIRECTIONS

It was shown by Jennings (1907) that the righting reactions may occur in such a way as to involve the migration of the rays *a*, *b* (fig. 3) in the direction to be expected (indicated by arrow) from the orientation of the tube feet of the starfish as a whole, and at the same time the migration of the rays *c*, *e* in the opposite direction (indicated by arrow). This divergent orientation is a necessary part of the righting reaction once the animal assumes the posture illustrated unless the tube feet of *c* and *e* release or be torn loose from the substrate. I have observed the righting animal to assume other similar postures upon which this divergent orientation of the tube feet follows with various modifications. In all such cases the mechanical pull exerted by the rays moving over the substrate could account for the orientation of the tube feet, provided of course that we could prove that a pull of this kind will orient the tube feet in its own direction.

The same is true of Mangold's starfish (fig. 4) in which all the tube feet, in spite of their diverse relation to the arm, are oriented in the direction of locomotion. This orientation was either brought about by mechanical factors acting on the tube feet directly, or else by a most complex central coördinating mechanism. There seems to be no morphological basis for the latter assumption.

When the starfish was in position 1 (fig. 5) it was moving in the direction of the lower arrow. When it came up against the obstacle (*o*) however, the tube feet of each ray immediately

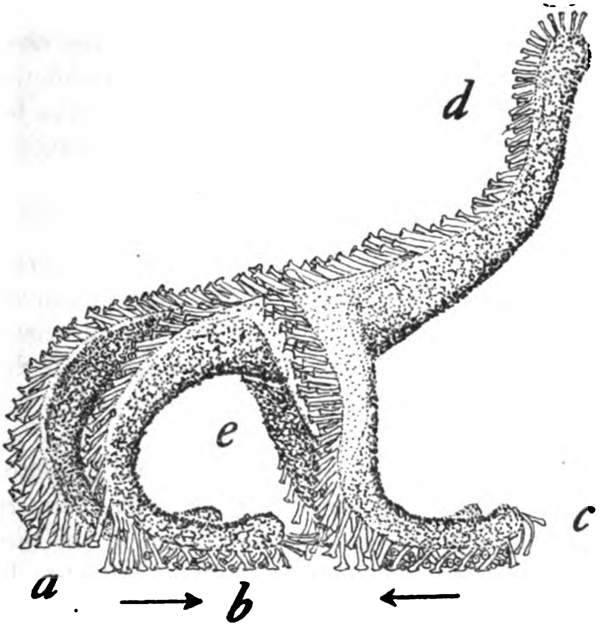


Fig. 3. A type of the righting reaction in which the rays which initiate the righting reaction, *a b*, migrate in harmony with the orientation of the animal as a whole while other rays, *e c*, which drag on the substrate are oriented in the opposite direction.

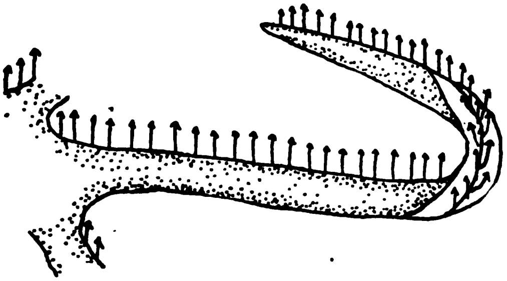


Fig. 4. Slender Armed Starfish Luidia ciliaris in Which the Arm is Curved but the Tube Feet are All Oriented in One Direction

Some are thus pointed to the right of the arm, others to the left and still others parallel with the arm. (After Mangold.)

changed their orientation to the direction indicated by the arrows at the tips of the respective rays. This results in the animal neatly avoiding the obstacle and migrating in the direction indicated by the upper arrow.

Assuming that the tube feet on one side of the obstacle (on arms *d*, *e*) were stronger than that on the other side (arms *a*, *b*) the resulting pull, provided it did orient the tube feet in its own direction, would explain the movements observed.

DIRECT EVIDENCE OF ORIENTATION BY PULL

The direct evidence on this point is contradictory at best. Tube feet will coördinate in the direction of their passively moved fellows (see above), but this explains a negative orientation to pull rather than a positive one such as is needed to harmonize with the above observations. Negative orientation to pull has been demonstrated in a previous paper.[5]

By grasping a starfish by the disk, or by its neurotomized or anaesthetized arms and dragging it slowly over the substrate, it was thought possible to orient the animal in the direction of pull. The results were negative in all cases but one, due to the fact that when thus disturbed the animal would become rigid and attach tightly to the substrate. A few migrated negatively and one gave a positive response; the remainder (out of 40) attached.

Several experiments were performed to test the possibility that a locomotor state may be established, or at least oriented, by direct pull of one part or another separated from it by a cut in the nervous system. Each arm of a rather large and sluggish starfish was neurotomized near the base and the animal was set against the side of a tall aquarium, with its former anterior down. The rays which were formerly anterior immediately took up locomotion in their own direction helped by gravitation and the fact that I occasionally loosened a tightly attached tube foot on a posterior ray. After it was well started this last procedure was unnecessary and locomotion continued down the side until the disk was at the floor of the aquarium. At this point the animal assumed the rigid state and would crawl no farther.

---

[5] *Loc. cit.*

This experiment was repeated on a smaller and more active specimen. The incisions were made with a very sharp knife and the animal was handled quickly and gently without removing it from the water. Locomotion down the side was more active than in the previous experiment. There were a few refractory tube feet but these were pulled loose by the activity of the anterior rays and soon there was coördination of a rather slow and vacillating kind. When the animal reached the floor

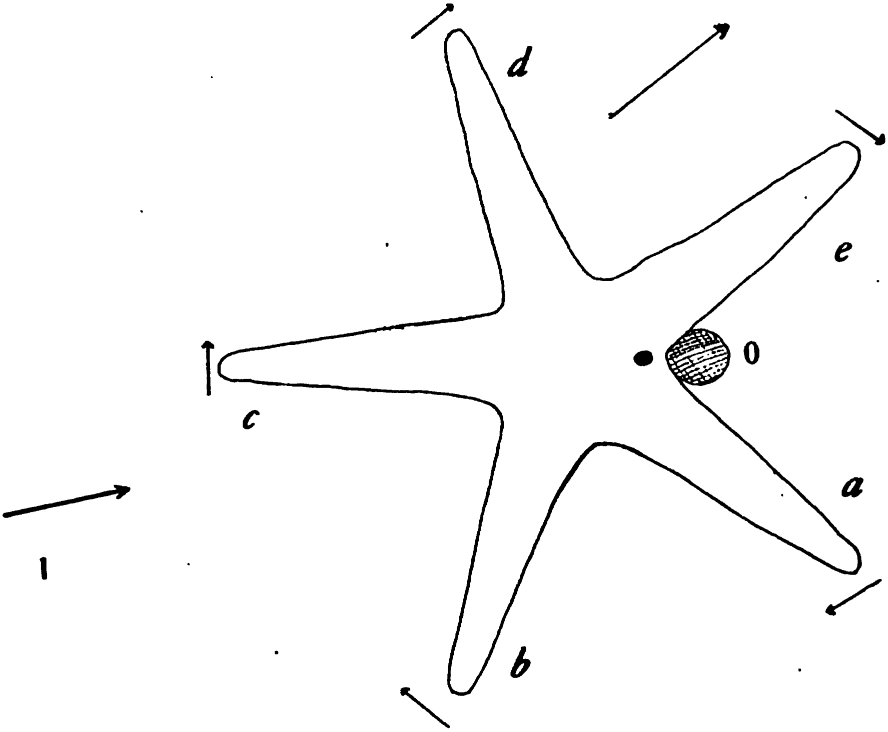


FIG. 5. THE DEVIATION REACTION

When in position 1 the animal was oriented in the direction of the lower arrow. On coming against the obstacle "o" the tube feet of each ray immediately reorient in the direction indicated by the arrows at the tips of the rays. The animal migrates around the obstacle and goes off in the direction of the upper arrow.

it was so well oriented that it migrated across the bottom and up the other side.

This starfish was then taken up and stimulated harshly on the various rays. When it was set down, the animal assumed the rigid, tightly attached state and remained so for some time The rays (*a* and *c*, see fig. 5) that became active first were not contiguous. They moved about in their sectors at random all the afternoon, while *b*, *d* and *e* remained attached. The next morning the starfish was in a moribund condition but had migrated across the aquarium during the night.

The essentials of these experiments were repeated many times with minor variations, the results differing between the two examples cited.

We may thus safely conclude that, while there is no neural or "neuroid" (Parker, 1919) transmission past a cut in the ambulacral nervous system, there may be a certain very limited amount of coördination between parts separated by such a cut and that this coördination is brought about by their mutual relationship to the substrate.

INDIRECT EVIDENCES AS TO THE FUNCTION OF PULL IN COÖRDINATION

As has been seen, the active but unoriented starfish will crawl in five separate directions with each of its five rays, when these rays are placed on independent substrate. In experimenting with separate flat free swinging substrata a certain amount of independence and divergence in direction was observed between the parts on the separate substrata.

I have never observed any continued tendency for such divergence of migration in normal starfish with all of the rays on the same substrate. It therefore seems to me that the factor of pull of part upon a part must have a rôle in the orientation of the normal starfish.

A study of the "deviation reaction" whereby an animal avoids an obstacle (fig. 5) brings out several points of interest illustrative of the relation of mechanical factors to coördination.

If the interradial area *a, e* is isolated from the central nervous system by deep cuts in the dorsal and ventral myodermal sheath the animal deviates normally and without any increase as measured on the spring recorder of the push exerted during deviation.

If on the normal actively migrating starfish the anterior interradial area is stimulated by prodding, in such a way as not to continuously obstruct the animal's progress, there will be no deviation reaction but either a stoppage, a continuation, or (rarely) a reversal of locomotion.

Furthermore, the amount of push which the animal exerts during the deviation decreases if the friction with the substrata is lessened by placing the animal on sand; and increases if the friction with the substrate is increased by putting a weight upon the animal. These observations point to the conclusion that the factors of the deviation reaction have to do with the mechanical relationship of animal to the substrate rather than with reflexes having their receptors at point of contact with the obstacle.

If the tips of one of the rays (Asterina) instead of the interradial dermis comes in contact with an obstacle connected with the spring recorder, the amount of pressure that it takes to cause a change in direction does not vary if a weight is put on the back of the starfish. The value is about 2.5 grams in each case. As might be expected from the configuration of the nervous system, this shows that the mechanism of the deviation reaction is altogether different from the mechanism involved in a change of direction when the tips of the rays are stimulated. In the latter case we are dealing with the relatively constant threshold of the receptors at the end of the ray while in the deviation reaction we are dealing with factors that vary with the mechanical data of load and friction.

In order that the obstacle may be left behind in the deviation reaction, there is usually a rotation of the animal of at least 70 degrees. The animal usually recovers from this, however, for there is a distinct tendency to continue crawling in the same direction as before the disturbance, even if the action involves an actual change of direction back from one assumed as a result of the disturbance.

SUMMARY

Coördination of the tube feet of the rigid starfish, like that of the gills, is a simple spread of extension or retraction. It is referable hypothetically to a simple nerve net. Tube feet may orient directly toward contact stimuli of the dermis or of the tube feet. This orientation may spread to the whole animal and result in positive locomotion.

Tube feet near the ends of the rays of active but unoriented specimens are oriented toward the tips of those rays on which they are situated. With the rays on separate substrata each one will walk toward its own tip.

Autotomy of a non-adaptive sort is due to a pathological sluggishness of the central part of the ambulacral system. The orientation at the tip of each ray does not spread through the central part of the ambulacral system. The result is that each arm pulls in its own direction until the rays part company.

Autotomy may be adaptive when the animal is caught by one ray, and frees itself by pulling away from the imprisoned arm. This is due in part to mechanical orientation.

Negative locomotion results from the retraction of the tube feet on the ray or rays stimulated. Because they are least affected by the spread of this retraction, those tube feet farthest away resume activity first. Their orientation spreads to the rest of the animal and because it is toward the tip of the rays farthest from the stimulus the resulting locomotion is negative.

The same factors operate in governing the orientation of the locomotor animal that initiate this orientation. In addition there are mechanical factors such as are involved in the deviation reaction.

The state of orientation, in some types of the righting reaction, in the locomotor starfish with a curved lateral arm and in the deviation reaction is broken up into areas in which the tube feet are oriented in different directions. This is highly adaptive. A possible physiological explanation is seen in the traction on the tube feet resulting from the movement of the rays over the substrate. Evidence for this hypothesis is drawn from

(1) neurotomized starfish, (2) starfish with the rays placed on separate substrates, (3) the mechanics of the deviation reaction.

REFERENCES

Bohn, G. 1908 Les essais et les erreurs chez les étoiles de mer et les ophiures. Bull. Inst. Gen. Psych., viii, 21–102, 56 figs. in text.

Clark, H. L. 1899 Synaptas of the New England Coast. Bull. U. S. Fish. Comm., xix, 21–31, 2 pls.

Cole, L. J. 1913a Direction of locomotion in the starfish (*Asterias forbesi*) Jour. Exp. Zoöl., xiv, 1–32, 5 tables, 9 figs. in text.

Cole, L. J. 1913b Experiments on coördination and righting in the starfish. Biol. Bull., xxiv, 362–369, 2 figs. in text.

Driesch, H. 1908 Science and philosophy of the organism. (Aberdeen University) ii, xvi + 381 pp.

Jennings, H. S. 1907 Behavior of the starfish (*Asterias forreri* De Loriol). Univ. Calif. Publ. Zool., iv, 53–185, 19 figs. in text.

Loeb, J. 1900 Comparative physiology of the brain and comparative psychology. (New York, Putnam), x + 309 pp., 39 figs. in text.

Mangold, E. 1908a Studien zur Physiologie des Nervensystems der Echinodermen, I. Die Füsschen der Seesterne und die Koördination ihrer Bewegungen, Pflüger's Archiv, cxxii, 315–360, 14 figs. in text.

Mangold, E. 1909b Studien zur Physiologie des Nervensystems der Echinodermen, III. Ueber die Armbewegungen der Schlangensterne und V. Uexküll's Fundamentalgesetz fur den Erregungsverlauf, Pflüger's Archiv, cxxvi, 371–406, 6 figs. in text and 4 tables.

Norman, W. W. 1900 Do the reactions of the lower animals against injury indicate pain sensations? Amer. Jour. Physiol., iii, 271–284.

Parker, G. H. 1919 The Elementary Nervous System. (Philadelphia, Lippincott) 229 pp., 53 figs. in text.

Plessner, H. 1913 Untersuchen über den Physiologie der Seesterne. Zool. Jahrb. Abt. f. Zool., xxxiii, 361–386, 7 figs. in text.

Preyer, W. 1886 Ueber die Bewegungen der Seesterne. Mit. a. d. Zool. Stat. zu Neap., vii, 27–127; 191–233, pl. 7, 27 figs. in text.

Romanes, G. J., and Ewart, J. C. 1881 Observations on the locomotor system of the Echinodermata. Philos. Trans. Roy. Soc. Lond. clxxii, Part III, 829–882, pl. 79–85.

Russo, G. 1913 Analisi e meccanismo del reflesso di raddrizzamento e di altri movimenti coordinati negli echinodermi. Atti. acc. Gioenia Catania, Serie 5, vi, Mem. 22, 1–14.

Scheinmetz, P. 1896 How do starfish open oysters? J. Mar. Biol. Ass., iv, n. s., 266–286, 9 figs. in text.

Steiner 1898 Die Funktionen des Centralnervensystems und ihre Phylogenese, iii, Die wirbellosen Thiere (Braunschweig, Friederich Vieweg) x + 154 pp., 1 pl., 46 figs. in text.

Sterne, C. 1891 Five souls with but a single thought, the psychological life of the starfish. Monist, i, 245–262, 6 figs. in text.

Von Uexküll, J. 1900 Die Physiologie des Seeigelstachels. Zeit. f. Biol., xxxix, 73–112, 4 figs. in text.

BOOK REVIEWS

ARTHUR F. HURST. *The Psychology of the Special Senses and their Functional Disorders.* Oxford Medical Publications. London, 1920, pp. 123.

These Croonian lectures, delivered before the Royal College of Physicians in 1920, present the results of the author's observation of the neuroses of soldiers in the British Army during the recent war. In connection with these observations, certain original experiments are also reported, directed toward a better understanding of the psychology of functional sensory disorders, and the evaluation of certain traditional stigmata of hysteria. Psychologists will enjoy the book and find it extremely suggestive. It deals an effective blow to clinical dogmatism and medical men should learn from it the danger to professional complacency involved in tolerating in their midst a man with a sense of scientific method.

In the first section the concept of hysteria is considered. The author rejects the classical distinction between permanent stigmata and temporary symptoms. Abnormal suggestibility as an essential hysteric characteristic is also rejected. Hysteria cannot exist in the absence of actual symptoms. It is "the condition in which hysterical symptoms are present," these being defined as symptoms resulting from suggestion and curable by psychotherapy. An important systematic point is involved here, and it would be interesting to know how far the author would extend it,—whether a similar conception would be applied to epilepsy, for example, or to paranoia.

Observations of "experimental malingering" before and after specific interrogation, produced reports of anesthetic areas similar to those regarded as typical areas of hysterical anesthesia. In addition to the results of suggestion by the examiner, emphasized by Babinski as the only type of hysterical anesthesia, hysterical anesthesias of an entirely different character are reported. Such anesthesia is often a sequel of the anesthesia caused by some organic condition, the perpetuation of sensory deficiencies originating in a condition of profound stupor or associated with paralyses due originally to peripheral nerve injuries and diseases or injury of the brain and cord; or they may be consequent upon disuse and vaso-motor spasm. Such anesthesias do not follow the lines of popular anatomy but correspond to the original areas organically affected. Whether they are perpetuated or disappear promptly with recovery from the paralysis depends largely on the direction of the patient's attention and expectation by the interests of the examiner, the mode of treatment, and the impressiveness of the condition. They are readily cured by suggestion and reeducation. Typical cases are cited.

The explanation suggested is based on the conception of perception as an active process. The anatomical basis for hysterical anesthesia depends on the removal of the structural foundations of the psychological act of attention, probably a change in synaptic resistance. Functional anesthesia is therefore due to inattention to the sensory areas involved. Treatment, whether by the faradic current or by reeducation, proceeds essentially by leading the patient to redirect his attention.

Observations of the normal range of variations of the superficial reflexes under the influence of such physical factors as temperature, repetition, condition of the bladder, show that controversies over the behavior of these reflexes in hysteria are due largely to ignorance of these normal variations. Thus the disappearance of the abdominal reflex with frequent repetition of the stimulus was experimentally shown to result from cooling of the skin rather than, as is commonly supposed, from fatigue.

The frequently made assertion that hysteria never leads to change in deep or superficial reflexes is refuted by showing that hysterical anesthesia may be associated either with complete bilateral loss or with inequality of the abdominal reflexes. Such absence or inequality of abdominal reflexes is very suggestive of organic nervous disease only if repeatedly observed, when the skin of the abdomen is uniformly warm, and the bladder empty. The plantar reflex also may be lost or weakened by disuse of the feet, whether due to organic or hysterical paralysis, as the result of diminished circulation and the consequent cooling of the skin.

Measures were made of 64 individuals with hysteric symptoms and of 170 healthy individuals, for pharyngeal sensibility, using a seven-step rating scale. Although much has been made of pharyngeal anesthesia as a diagnostic symptom of hysteria, the data "show conclusively that pharyngeal sensibility is no more deficient in individuals suffering from hysterical aphonia or other hysterical symptoms, such as paralyses, contractures, fits, blindness, or deafness, than in individuals who neither are suffering nor have ever suffered in this way." Distribution graphs of the variations in pharyngeal exciteability in the various groups are given, and they afford a neat warning of the danger of generalising either individual or serial clinical findings, so long as they are unchecked by control observations.

Cutaneous hyperesthesia when it occurs in hysteria, it is suggested, is based on excessive attention, and is readily suggested by the expectant examiner. Even in other conditions the areas of skin involved are much less constant than is often supposed. Undue or unusual attention to a pain, originally organically caused, may so open the synapses of the paths of pain conduction that an acquired sensibility and persistent hysterical pain may result. Such hysterical pain cannot be distinguished from pain caused by organic disease by its character nor by the absence of associated phenomena. But it may be relieved by psychotherapy. Being so cured, and caused by the suggestion of the original pain, it is to be called hysterical.

The two longest chapters are given to hysterical deafness and blindness. In order to hear one must listen; to see, he must look. Listening and looking are active adjustments of attention, and their physical counterpart ranges from the adjustment of the accessory apparatus of the sense organs to the probable extension of dendrites which brings into more intimate connections the neurones of the sensory paths concerned. After temporary deafness, produced by concussion or disease, the patient may "cease to listen" and therefore cannot hear. This is the most common form of hysterical deafness. It is suggested by the original deafness and can be cured by explanation. Disturbance of the auditory-motor reflex in such cases indicates that sub-cortical as well as cortical synapses may thus acquire faulty habits, and the effect may be so profound that it persists during sleep.

Controlled tests show that "the supposed association of hysterical anesthesia of the external ear with hysterical deafness is a complete fallacy, and that anesthesia is likely to occur in a deaf ear if looked for, whether the deafness is organic or hysterical, so long as the individual is sufficiently suggestible and not too well educated." Another observation, entirely in line with actual measurements reported in this country, is the following: "The greater frequency of grotesque hysterical symptoms among hospital than private patients, and among private soldiers than officers, is doubtless due to the greater intelligence and greater development of the critical faculties of the latter."

The chapter on hearing gives a series of illustrative cases and is full of shrewd observations relating to hysterical deafness, its psychological mechanism and treatment. Hysterical hyperaceusis is explained as due to a mechanism exactly the reverse of that leading to hysterical deafness.

The account of hysterical blindness follows a general pattern similar to that of hysterical deafness. Various detailed signs which have been "copied from one book to another" are shown to have no significance or to be pure artefacts. Compensatory over-action of the frontalis muscle, when effort is made to keep the eye open, is seen to be of no value in differentiating organic from hysterical ptosis. Babinski's platysma sign is found to be misleading. Even the classical "retraction of the field of vision," so often pronounced a "permanent stigma" and an "emblem" of hysterical sensibility, is shown to result from the narrowed field suggested by the perimeter, and the "spiral" fields, hitherto regarded as stigmata of hysteria, are determined by the technique employed in using the perimeter. Naïve subjects in "experimental malingering" give the classical pictures also.

The general doctrine of hysteria, the synaptic theory of anesthesia and hyperesthesia, and disturbed reflexes, and the account of the rôle of suggestibility in hysteria, although highly interesting and valuable, do not seem to the reviewer to be the most striking features of the book. Its most valuable feature consists in the exhibition of what is likely to happen to the rules of thumb of medicine when an investigator, equipped with a sense of scientific method undertakes to evaluate them. The book marks a real step forward in neuro-psychiatry,—the substitution of the canons of proof for the word of the master. Such work might well be carried further by the coöperative work of neurologists and psychologists.

H. L. HOLLINGWORTH,
Columbia University.

VOLUME II APRIL, 1922 NUMBER 2

THE JOURNAL OF COMPARATIVE PSYCHOLOGY

Continuing Psychobiology and the
Journal of Animal Behavior

EDITED BY

KNIGHT DUNLAP
Johns Hopkins University

AND

ROBERT M. YERKES
National Research Council

IN ASSOCIATION WITH

MADISON BENTLEY
University of Illinois

HARVEY CARR
University of Chicago

WALTER B. CANNON
Harvard University

RAYMOND DODGE
Wesleyan University

SHEPHERD I. FRANZ
Government Hospital for the Insane

GILBERT V. HAMILTON
Santa Barbara Clinic,
Santa Barbara, California

SAMUEL J. HOLMES
University of California

WALTER S. HUNTER
University of Kansas

HERBERT S. JENNINGS
Johns Hopkins University

GEORGE H. PARKER
Harvard University

EDWARD L. THORNDIKE
Columbia University

MARGARET F. WASHBURN
Vassar College

JOHN B. WATSON
New York City

WILLIAM M. WHEELER
Harvard University

PUBLISHED BI-MONTHLY BY
WILLIAMS & WILKINS COMPANY
BALTIMORE, U. S. A.

Entered as second-class matter April 4, 1921 at the post office at Baltimore, Maryland, under the Act of March 3, 1879

Price per volume, net postpaid
$5.00, United States, Mexico, Cuba
$5.25, Canada
$5.50, other countries

Made in United States of America

NEW VITAMINE BOOKS

THE VITAMINE MANUAL—By Walter H. Eddy, Ph.D. *Associate Professor of Physiological Chemistry, Teachers College, Columbia University.*

This book answers the demand for concise information about the new food factors. The author has collected the existing data on the subject and put it into a form which would be available to both students and laymen.

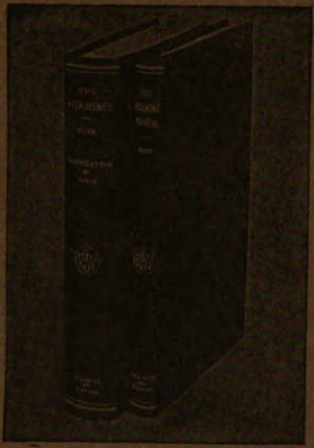
Comments That Speak

————: "I consider The Vitamine Manual one of the best books on vitamines that I have seen yet." "It has cleared up many questions and is of great value to teachers of nutrition." "It contains much material that will be valuable to the teachers in our schools." "We are adding it to our list of text and reference books which are sent to home economics teachers."

Bibliography of 500 references.

THE VITAMINE MANUAL will prove useful to Chemists, Physiologists, Biologists, Food Manufacturers and Distributors, Dietitians, Nutrition Experts, in fact to all individuals interested in promoting correct habits of living and correct habits of diet.

Published—September, 1921
121 Pages—6 x 9



INTERESTING
AUTHORITATIVE
INSTRUCTIVE

THE VITAMINES—By Casimir Funk, Ph.D., *Associate in Biological Chemistry, Columbia University, College of Physicians and Surgeons.*

Authorized translation from Second German Edition by Harry E. Dubin, Ph.D.

The Lancet (London), 1914: "Altogether this (the First Edition of Die Vitamine) is a most interesting and suggestive treatise—a pioneer work opening up many new fields of research of great practical importance. We hope the author will see his way to publish it in English."

Second Edition, February, 1922

THE VITAMINES is comprehensive and authoritative. A copy should be on the desk of every individual interested in nutrition. Teachers, students, and scientific investigators will find it invaluable as a stimulus to thought and further research, as it is not an elaboration of technicalities. Its bibliography of 1595 references is wonderfully complete.

This book was translated and published because it was the best book we could locate in this special field.

Date of publication—February, 1922
Second Edition, 595 pages—6 x 9

WILLIAMS & WILKINS COMPANY
Publishers of Scientific Books and Journals
Mt. Royal and Guilford Avenues
Baltimore, Md.

Kindly send me, postpaid:

One copy of THE VITAMINES, by Funk ($5.50, U. S.; Canada, $5.75; other countries, $6.00).

One copy of THE VITAMINE MANUAL by Eddy ($2.50, U. S.; other countries, $2.75).

I enclose check (or money order) for the amount; (or) I will remit on receipt of statement; (or) I wish to see the book(s) on ten days' approval and will remit or return same, if not satisfactory, within ten days from receipt.

Signed..

Address..

COÖRDINATION IN THE STARFISH

III. THE RIGHTING REACTION AS A PHASE OF LOCOMOTION (RIGHTING AND LOCOMOTION)

W. F. HAMILTON

The righting reaction of starfish, because it involves a "purposive" or "adaptive" act that may be reached by any one of a number of systems of freely combined movements has received the attention of many experimenters. Some have held that it is the product of simple reflexes while others have preferred to regard it as the manipulation of a super-physical "entelechy" diagnosed by the fact that a given result or "purpose" may be achieved in any number of ways. To these observers the righting reaction is a connecting link between reflex behavior and the conduct of higher forms. A brief summary of the literature will suffice to show the need of further research.

LITERATURE

Vulpian (1866) from cutting experiments assumed a righting center in the nerve ring. Krukenberg (1881) denied the existence of such a center for certain species but admitted it for others. Romannes and Ewart (1881) described the righting of normal, transected and neurotomized specimens but did not analyze it on a physiological basis. Preyer (1886) made a careful study of the righting reaction and, on account of its extreme variability and the closeness with which it adapts itself to environmental circumstances, came to the conclusion that it had a basis of intelligence served by anatomical centers.

Jennings explains righting by appealing to a unified impulse which is, by implication, the same as that which determines locomotion. He lists seven types of righting reaction, each capable of many minor variations, and a large number of environmental and internal factors that may determine the type of reaction

According to this author the variability of the reaction is an index to the complexity of the factors which govern it; and an analysis of these factors is wholly beyond the scope of present physiology.

Cole (1913a) admits the function of a unified impulse in the righting reaction, but contends that since its direction is not related to the direction of locomotion before and after the righting reaction, it is not determined by continuation of the locomotor impulse.

Loeb (1900) attributes righting to positive stereotropism of the tube feet such that when they are not in contact with the substrate they feel about at random until they touch it and then start pulling the animal over. The stimulus produced by the pulling of two or three arms in the same direction has an inhibitory effect on the other arms.

In addition to this inhibition, according to Moore (1910a and b) there is an active coördination of the arms which becomes weaker as it spreads to the arms more distant from those initiating the righting. A common or normal method of righting is distinguished in which two adjacent rays twist their ventral sides toward each other. This may be modified by "(1) inequalities in the length of the arms, (2) injuries to certain arms, and (3) any initial twist an arm may have due, to its position before the animal was laid on its dorsal side." These modifications are said to account for the seven types of righting reactions described by Jennings, 1907. Moore states emphatically that the righting is not due to stimulation of the dorsal sheath, but is initiated by the chance contact of the tube feet with the substrate. His description (1918) of the movements of the tube feet before attaching savors somewhat of trial and error, and is not congruent with his statement (1910a and b) that there is a common or normal method of righting which most starfish use.

After studying the movements of starfish in response to strychnine and nicotine, Moore (1916, 1917, 1918 and 1920a) comes to the conclusion (1920b) that random movements are not a real part of the righting reaction, but that it is the necessary result of reflexes whose receptors are in the dorsal sheath of each ray! In this analysis he leaves out of account entirely the "common or normal way" in which starfish right themselves and the reasons why two rays will *simultaneously* twist so that their ventral sides face each other (1910a). According to this paper (1920b) dorsal flexures play the important rôle in the righting reaction, whereas, previously, like most other observers, he neglected these dorsal flexures altogether and held that the righting reaction was initiated by lateral twistings of certain arms. *Astropecten* is the only starfish reported (Romannes and Ewart, 1881), so far as I know, that initiates its righting reaction by means of dorsal flexures of the rays.

In the light of previous studies[1] of this series the following analysis of the righting action is presented in terms of the relation of the movements of the arms to those movements of the tube feet which are involved in locomotion.

ILLUSTRATIONS OF THE TENDENCY OF THE ARM TO SET ITSELF AT RIGHT ANGLES TO THE DIRECTION OF ORIENTATION OF ITS TUBE FEET

If an active starfish is suspended and a solid object is brought in contact with the tip of one of the rays there will be an active orientation of the tube feet toward the tip of the ray. This will be followed almost immediately by a dorsoflexion of the tip of the ray (figs. 1 and 2). The ray can be said to set itself more nearly at right angles to the actively oriented tube feet. This dorsoflexion will not follow such stimulations of the tip of the ray as result in retraction of the tube feet. It is a product of local reflexes for it will occur in an amputated ray.

If a tube foot in the middle of a ray is allowed to attach to an object and the object is then pulled to one side, the tube foot with it, the other tube feet will also move out to the same side and seemingly reach out for the object to which the tube foot is attached (see second study of this series). Now, if a sufficient number of tube feet become orientated in this manner there will be a lateral twist of the ray toward the object (fig. 3). Here again the ray can be said to set itself more at right angles to the orientation of its tube feet, by lateral as well as by dorsal movement (see also Jennings, 1907, page 93).

---

[1] Journal of Comparative Psychology, Vol. 1, December, 1921, pp. 473–488; Vol. 2, pp. 61–73.

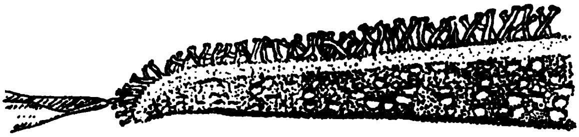


FIG. 1. TIP OF THE STARFISH RAY BEING STIMULATED BY GENTLE CONTACT

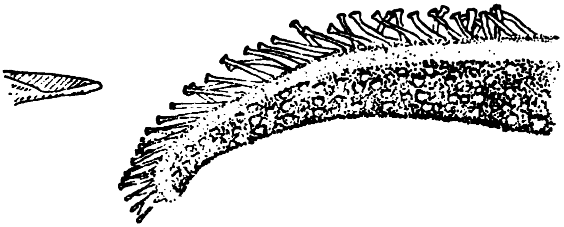


FIG. 2. AFTER STIMULATION AS IN FIGURE 1

The tube feet become actively oriented toward the tip of the ray and the ray sets itself more nearly at right angles to the oriented tube feet by a dorsal movement.

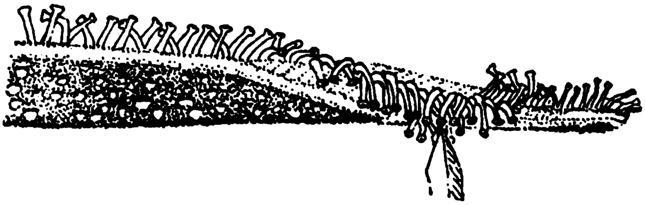


FIG. 3. THE TUBE FEET ARE CAUSED TO ORIENT TO THE SIDE BY CONTACT STIMULATION

The ray sets itself more nearly at right angles to the direction of their orientation by a lateral twisting.

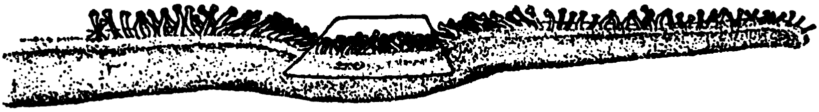


FIG. 4. THE TUBE FEET ABOVE AND BELOW THE CELLULOID PLATE ARE ORIENTED TOWARD IT

The ray sets itself more nearly at right angles to the direction of their orientation by both dorsal and ventral bending.

The slender armed species of starfish (*Evasterias troschelii*) was suspended and a flat piece of celluloid was swung by a thread to the ventral side of one of the rays. The tube feet which were oriented toward the tip of the ray immediately seized the object and "walked" it in the direction of the disk. This involved the orientation toward the object of several tube feet, both above and below it and the bending of the ray so as to receive the object in a sort of hollow (fig. 4). The tube feet in contact are of course undergoing the step reflex, but above and below, where the tube feet are all directed toward the object it can be said that the ray tends to set itself more at right angles to the orientation of the tube feet upon it. An illustration of this principle has been described by Jennings (1907) and Mangold (1908a) in the humping up of a ray in the region of a morsel of food which is being carried by the tube feet toward the mouth.

If the tube feet are not oriented at all, as in case of the rigid starfish which has been inverted or a starfish that has been suspended ventral side down and left undisturbed for a long time, a ventral flexion of all the rays is apt to follow. In case the suspended starfish is touched, however, there will be dorsal, ventral or lateral movements of the rays depending upon which way the tube feet have been caused to orient. Touching the dorsal sheath of the ray (Moore, 1920b) activates the tube feet on that ray (Romannes and Ewart, 1881) and since their normal orientation is toward the tip of the ray there will be a dorsal flexure as in figures 1 and 2.

The activity of the tube feet may spread to those of other rays and be followed by movements of the rays themselves, which will be analyzed later as a part of the righting reaction.

The ventroflexion of the rigid starfish (inverted) is more or less analogous to the state described by Preyer (1886), Greenwood (1890) and Moore (1920a) as a result of nicotine poisoning and which I have confirmed for *Pisaster*. The chief difference seems to be that the tube feet of the nicotinized *Pisaster* are completely retracted while those of the rigid animal show a certain amount of extension but no particular orientation. The strength of the spasm is greater in the nicotinized animal.

The righting movements of the nicotinized starfish whose tube feet are wholly retracted, as described by Moore (1920b) emphasize the fact that the tube feet do not have to be extended to be oriented. The mechanisms of extension and of orientation are wholly independent (see second paper of this series). Upon examining *Pisaster* in the act of righting one often sees the tube feet bent in a certain direction but not extended out of the ambulacral furrow.

INTERPRETATION OF THE RIGHTING REACTION AS A PHASE OF LOCOMOTION

In general terms I believe that the righting reaction is an alternative phase of locomotion. If an actively migrating starfish is inverted the tube feet extend out in the direction of their orientation (fig. 5). In this state they are ready to give the step reflex upon contact stimulation. There are reflex connections between some part of the ambulacral nervous system and the myodermal sheath which act, in case the step reflex is not initiated by contact stimulation, in such a way that the ray by twisting or bending or both, sets itself more nearly at right angles to the direction of orientation of the tube feet. Thus the rays *b*, *c*, *d* (fig. 6) rise orally and bend over toward the anterior rays *a*, *e*. The latter twist toward each other and bend down. This brings their tube feet in contact with the substrate and initiates the step-reflex. Because the tips of these rays are doubled under, the direction of their migration is toward the disk. The righting is then completed as in figure 7.

The tube feet have been regarded by most previous writers as taking hold of the substrate and pulling the animal over. Observations of the reactions as it occurs on sand show that this pulling is not a fundamental or necessary part of righting. The step reflexes of the tube feet on coming in contact with the sand are very vigorous. The disks plough back through the sand and scatter the grains to a distance of two centimeters. The movements thus started continue until the initiating rays have moved back under the disk and the other rays have moved up over the disk far enough to over-balance the animal and complete the

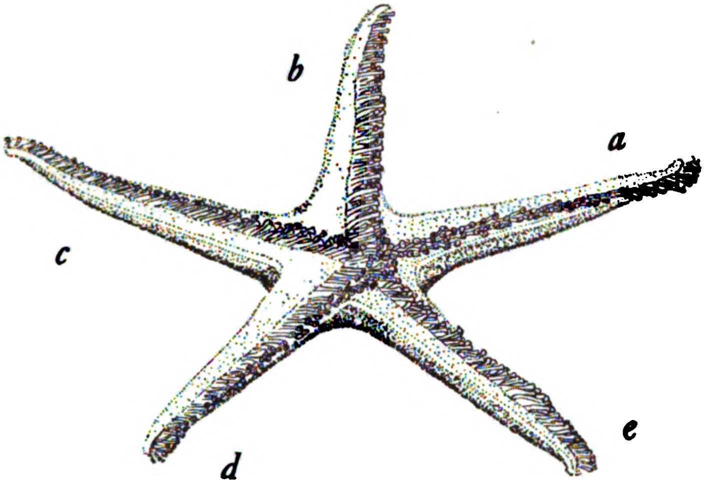


Fig. 5. Beginning of the Righting Reaction of an Oriented Specimen

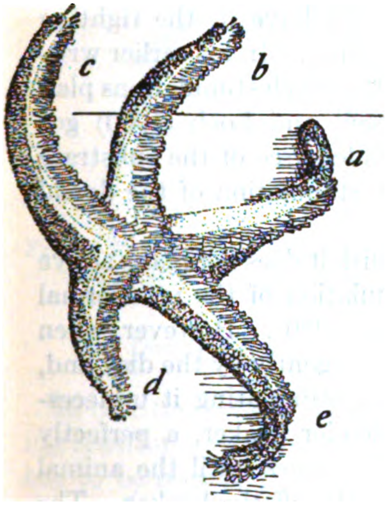


Fig. 6. The Right Reaction of an Oriented Specimen Continued

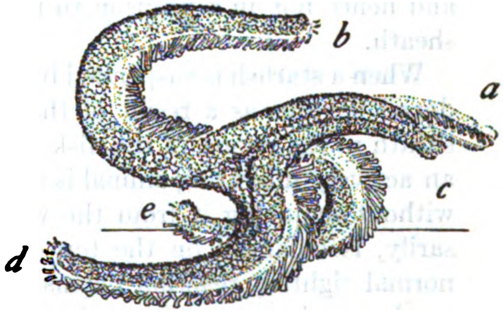


Fig. 7. Later Stage in the Righting Reaction of an Oriented Specimen

In figures 5, 6 and 7, it will be noted that the arms so bend as to set themselves more at right angles to the direction of orientation of the tube feet. Direction of locomotion previous to inverting, toward *a*, *c*.

somersault. The animal does not *pull* itself over; it *walks* itself over.

Pulling is, however, a normal part of the righting reaction as it occurs on a solid substrate. It is also a part of the step reflex and since attachment increases with the resistance to the step (pull) (see first paper of this series) and the resistance to the step in the initiation of the righting reaction is considerable it follows that attachment is correspondingly tight and that pulling is the most noticeable activity of the tube feet. But the pulling is only a phase of the step reflex and the step reflex is the important thing.

If, then, the righting movements of the arms are dependent upon the initial stages of the step reflex (oriented tube feet) and the righting movements of the tube feet are slightly modified step reflexes, righting is itself but a phase of locomotion.

Moore (1920b), however, contends that "The excitation of the sensory cells of the dorsal sheath initiates dorsal flexure of the ray." If this excitation of the dorsal sheath is an essential part of the righting reaction, as Moore would have it, the righting reaction is more than a phase of locomotion. In his earlier writings Moore cites experiments to show that such stimulations play no part in the reaction. Preyer (1886) and Loeb (1900) got righting reactions from animals suspended free of the substrate and hence not in a position to receive stimulation of the dorsal sheath.

When a starfish is suspended by the disk it does not make active dorsal flexures as a result of the stimulation of the myodermal sheath in the region of the disk (Moore, 1920). However, when an actively migrating animal is picked up gently by the disk and, without removing it from the water or stimulating it unnecessarily, is balanced on the top of a slender beaker, a perfectly normal righting reaction begins and continues until the animal reaches such a posture (fig. 8) that it falls off the beaker. The rays *a*, *e*, which were anterior during locomotion bend toward each other and down. The other rays bend up and toward *a*, *e*. The arms follow out in every respect the movements with regard to the orientation of the tube feet, just as they usually do in the normal righting reaction.

Contact stimulation of the dorsal side of the ray or of the tube feet themselves, therefore, is not a necessary part of the righting reaction. The reaction is not brought about by coördinating and inhibiting impulses sent out from tube feet stimulated by contact. It is rather an alternative phase of the locomotor state that is manifest when the tube feet are not stimulated to execute the step-reflex.

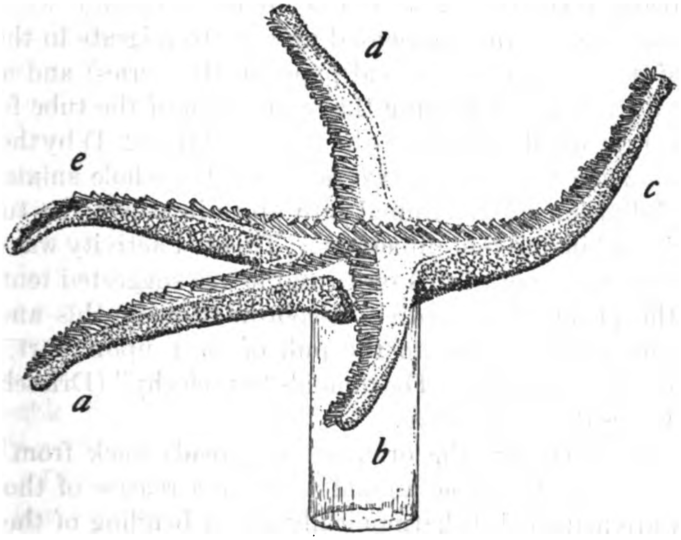


FIG. 8. THE RIGHTING REACTION AS IT OCCURS WHEN AN ORIENTED SPECIMEN IS BALANCED ON A SLENDER BEAKER WITH ONLY THE DISK RECEIVING CONTACT STIMULATION

Direction of locomotion previous to inverting toward *a*, *e*

In case the animal, when it is inverted is not oriented, the righting reaction is not well organized at first. Complete orientation has to be established before the animal will right harmoniously. These "false starts" are divided by Jennings (1907) into six varieties, which together with the method just described gives seven different types of righting reactions recognized by this author. The false starts may be divided into two classes: (1), in which one ray initiates the righting; (2), when more than two rays attach in righting.

If one ray initiates the righting of a normal starfish with no initial twist of the arms, it is usually because the initiating ray was anterior before the animal was inverted and the other rays lift up ventrally as soon as they are free of the substrate. This occurs very rarely.

More than two rays sometimes attach when the animal (normal and with no initial twist to the rays) is not fully oriented before being inverted. This is due to the tendency which each ray possesses (on the unoriented animal) to migrate in the direction of its own tip (see second paper of this series) and a consequent dorsoflexion following the orientation of the tube feet.

This type of false start may be recovered from: (1) by the spread of orientation from one or two rays over the whole animal or (2) the subdivision of the animal into areas in which the tube feet are oriented in different directions. This last activity was studied in the second paper of this series and it was suggested tentatively that the peculiarly adaptive discoördination in this and other reactions might be due to the pull of part upon part, acting through the substrate. The animals "entelechy" (Driesch, 1908) is, so to speak its substrate.

In case, however, the orientation spreads back from one or two rays over the whole animal we have a release of those rays which are attached disharmonically and a bending of them over toward the rays used in righting.

The movements upward of the arms we have seen are not due to the spread of coördinating impulses from the stimulated contact receptors of the initiating rays. Nor do I believe that the release of the tube feet on these arms is a result of inhibitions sent out from the initiating rays. When the orientation of the initiating rays spreads back to the rays which are attached disharmonically and tugging in the direction of their own tips, there is an almost complete reversal of the orientation of their tube feet. Because the step reflex involves release in the latter part of the backsweep, the tube feet of the arms in question release as soon as their orientation reverses and the arm turns up and over toward the initiating rays. The inhibition of attachment is thus a phase of the step reflex rather than a discrete part of the righting reaction.

Cole (1913a) concluded from twenty-four observations that the direction of locomotion before and after inverting a starfish was opposite the direction of righting. A careful study of his table shows, however, that the difference between the directions of locomotion before and after righting is 0.7 interradius for the average of his observations. This he speaks of as no difference at all when he says that the starfish migrate after righting in the same general direction as they did before righting. We also find that the difference in direction between the arms used in righting and those that were anterior before inverting is 1.5 interradius Cole concludes that the starfish right in the opposite direction from that in which they crawl. This statement is somewhat exaggerated since the deviation is only about twice what he considers no deviation at all (0.7 interradius) and only three-tenths of the circumference of the animal.

To clear up the relationship between the physiological anterior and the arms used in righting, seventy-five experiments were made with twenty-six starfish (twenty *Pisaster* and six *Asterina*). The starfish were in active locomotion. Manipulation was as gentle as possible, the animal being picked up by the disk and inverted quickly without, in most cases, lifting it above the surface of the water. Directive factors in the surroundings such as light, areas of shadow, etc., were excluded by rotating the animal in successive trials.

Records were taken of the direction of locomotion and of the arms which, after being inverted, the animal first twisted and bent down toward the substrate. These two findings were compared and the shift in either direction of the leading rays was recorded. Its average (sixty-four records) proved to be 0.38 interradius.

The rays that turned down first were not always, of course, the same as those the animal used in righting. The rays used in righting were recorded. The shift between the rays anterior in locomotion before inverting and the rays used in righting proved to average (sixty-two observations) 0.6 interradius. The difference between this shift and that recorded by Cole (1.5 interradius) is probably a function of careful handling and the use of a larger number of representative specimens.

The shift recorded in the same way between the directions of locomotion before and after righting proved to be 0.57 interradius (forty-four observations). After righting, the anterior shifts slightly back toward its original direction because the average shift after righting is less than during righting. This shows more markedly in the averages drawn from Cole's table.

The return of the anterior toward its original direction is an example of the tendency which we have noticed in connection with the deviation reaction (see second study of this series) for the direction of orientation to return to its original status even after having been actively oriented in some other direction.

Cole (1913a) has shown very conclusively that the impulse to locomote tends to keep the same general direction even after the starfish has been taken up and held inverted by the disk until the rays drooped aborally, and set down again in a non-directive chamber. The tendency to keep in the same direction was of course only general as there was also a rotation of the anterior toward the right or toward the left and certain aberrant deviations of from one-half to two and a half interradii, occurring quite frequently. In counting up these deviations from Cole's table 3 it was found that they amounted to a sum total of 217 interradii in four hundred and ninety-nine trials. This amounts to a shift of 0.43 interradius per trial which is quite comparable quantitatively with the figures (0.38, 0.60, 0.57 interradii) obtained from the status of the direction of orientation throughout the righting reaction.

The fact that orientation persists in one direction during the righting reaction, to a degree quantitatively comparable to ice persistence in ordinary locomotion (Cole) is additional evidents that righting is a phase of locomotion.

The righting reaction can not be said to be a manifestation of positive stereotropism of the tube feet because the determining factor is not contact excitation of these organs but rather the physiological orientation of the starfish. A state of affairs exists in the central nervous system which determines the direction in which the tube feet are protruded and hence the direction of locomotion. This same state of affairs determines the movements of righting.

SUMMARY

The righting reaction is determined by the locomotor orientation of the starfish and not by contact excitation. It is hence a phase of locomotion and not an example of stereotropism.

The movements of the arms are explained on the assumption of reflex connections by which the arms are bent or twisted more nearly at right angles to the direction of orientation of the tube feet.

Evidence for this attitude is drawn: (1) from an analysis of the movements of the tube feet and arms; (2) from an analysis of the righting reaction when the tube feet are prevented from attaching by inverting the animal on sand; (3) from the fact that contact excitation of the dorsal myodermal sheath is not an essential part of the righting reaction, and (4) from the fact that the direction of orientation persists during the righting reaction to a degree quantitatively comparable to its persistence in ordinary locomotion (Cole, 1913a).

REFERENCES

COLE, L. J. 1913 a Direction of locomotion in the starfish (*Asterias forbesi*). J. Exp. Zool., **14**, 1–32, 5 tables. 9 figs. in text.

1913 b Experiments on coordination and righting in the starfish. Biol. Bull., **24**, 362–369, 2 figs. in text.

JENNINGS, H. S. 1907 Behavior of the starfish (*Asterias forreri* De Loriol). Univ. Calif. Publ. Zool., **4**, 53–185, 19 figs. in text.

GREENWOOD, M. 1890 On the action of nicotine upon certain invertebrates. J. Physiol., **11**, 570–605.

KRUKENBERG, C. FR. W. 1881 Beträge zu einer Nervenphysiologie der Echinodermen. In Verg. Phys. Studien (Heidelberg, Carl Winter's Buchverhdg.) 2 Reihe, 1 abth., 76–82, 2 figs. in text.

LOEB, J. 1900 Comparative physiology of the brain and comparative psychology. (New York, Putnam), x, 309 pp., 39 figs. in text.

MOORE, A. R. 1910 a On the righting movements of the starfish. Biol. Bull. **14**, 235–239, 1 fig. in text.

1910 b On the nervous mechanism of the righting movements of the starfish. Amer. J. Physiol., **27**, 207–211, 2 figs in text.

1916 The action of strychnine on certain invertebrates. J. Pharm. and Exp. Therap., **9**, 167–169.

1917 Chemical differentiation in the nervous system of invertebrates. Proc. Nat. Acad. Sci., **3**, 598–602.

1918 Reversal of reactions by means of strychnine in planarians and starfish. J. Gen. Physiol., **1**, 97–100, 3 figs. in text.

Moore, A. R. 1920 a The action of strychnine and nicotine on the neuromuscular mechanism of *Asterias*. J. Gen. Physiol., **2**, 201–204, 5 figs. in text.

1920 b Stereotropism as a function of neuromuscular organization. J. Gen. Physiol., **2**, 319–324, 4 figs. in text.

Preyer, W. 1886 Ueber die Bewegungen der Seesterne. Mit. a. d. Zool. Stat. zu Neap., **7**, 27–127; 191–233, pl. 7, 27 figs. in text.

Romanes, G. J., and Ewart, J. C. 1881 Observations on the locomotor system of the Echinodermata. Philos. Trans. Roy. Soc. London, **172**, Part III, 829–882, pl. 79–85.

Vulpian, A. 1886 Leçons sur la physiologie générale et comparée du systems nerveux, faites au Museum d'histoire naturelle (Paris, Germer Baillière), 737–742.

THE CONGENITAL SEXUAL BEHAVIOR OF THE YOUNG MALE ALBINO RAT

CALVIN P. STONE[1]
University of Minnesota

INTRODUCTION

1. Purpose of investigation

The general use of experimental technique in the study of congenital behavior of lower and higher animals reflects a gradually changing trend of psychological interest in this subject. Interest is shifting from problems centered in the determination of significant relationships between conscious and organic processes to those defining units of response and analyzing the stimuli by which they are activated. As yet, however, in the field of animal psychology, investigations of congenital behavior have not been sufficiently intensive to give a complete account of either the overt patterns of activity or the activating stimuli. They have furthered an understanding of limited aspects of particular responses, given valuable suggestions along lines of methodology, and copiously illustrated the erroneous nature of many of the older conceptions concerning native behavior; but, in general, the scope of these accounts is too limited to place our knowledge of the subject as a whole on a fundamental working basis. For this reason there is need, at the present time, of comprehensive studies of fundamental types of native behavior. Intensive studies will yield data that may be used as guides in the reorganization and expansion of current views of these activities.

For the advancement of the science of animal behavior, there is need of intensive genetic studies of complex patterns of native behavior to ascertain the life histories of both the constituent elements and the patterns as wholes. With respect to the nature of activating stimuli our knowledge is very incomplete. For the most part investigators have dealt with the external stimuli alone. They have overlooked the internal factors. Now, to really understand the activation of native patterns of response, it is necessary to take the latter into account as well; for the external stimuli merely discharge the elaborate and complex neuromuscular and glandular mechanisms pre-organized by the action of potent internal factors operating within the organism. A preliminary survey of the internal factors operating would seem to indicate that at least two distinct types can be recognized. There is a group which underlies the development and integration of the neuro-muscular and glandular mechanisms, and another that serves to keep the mechanisms in a state of readiness for response to particular patterns of external stimulation.

---

[1] I wish hereby to acknowledge my indebtedness to Dr. K. S. Lashley at whose suggestion and under whose direction this experiment was conducted.

The field of congenital sexual activity offers a favorable opportunity for an intensive and comprehensive study of a type of behavior both typical and universal. It is a type which may be satisfactorily studied in the ordinary laboratory animals; and it should yield data of both theoretical and practical importance for many general phases of congenital activity. On this account congenital sexual behavior was subjected to experimental study in this investigation. The study is concerned primarily with the copulatory act of the young male albino rat.

On the whole the rat is a very satisfactory animal for observation in a study of sexual behavior. It thrives well in confinement, becomes sexually mature in a relatively short time (sixty to ninety days), and displays its sexual behavior, under appropriate stimulation, throughout the entire year. The copulatory act of the animal is one that may be studied from many aspects. Its appearance in post-natal life is late enough to make possible a genetic study of its development; and it persists throughout a span of the rat's life sufficiently long to enable one to observe the alterations with age, experience, and modified conditions of the general metabolism.

In this paper an attempt will be made to set forth salient data concerning: (1) The constituent elements of the copulatory pattern of activity and the serial and functional relationships they manifest, and (2) the kinds of external stimuli adequate to initiate the copulatory act and the manner in which their influences are mediated through the receptors. In a subsequent paper data bearing upon internal factors underlying sexual functions will be presented.

2. Previous studies of sexual behavior

It will be of value to consider briefly the experimental studies of sexual behavior of the rat and those of other animals, as well, which have a direct bearing on the present study. This literature will be, therefore, the subject of immediate consideration.

Banta ('14) gives an excellent account of the mating of the wood frog. Any moving object which came within the radius of several feet attracted the male and caused pursuit. Masculine aggression was increased or lessened by the response of the object clasped. The vigorous struggles of a male when clasped by another male were followed by relaxation of the clasp and dismounting of the latter. Frequently several males were seen competing for a single female. If one succeeded in getting into a favorable position on the back of the female and fixed his forelimbs firmly about her he usually succeeded, by vigorous kicks of the hind legs, in forcing other competitors to release their holds. Sexual excitement reached its highest pitch at 52°F. and was almost wholly wanting at 45°F.

The conjugation of the crayfish was studied by Andrews ('14). He made a very detailed analysis of the pattern of copulatory acts. Seventeen distinct elements were discovered. Apparently the first elements of the pattern were set off by purely local stimuli afforded by other crayfish in the immediate presence of the male. Through the amputation of bodily structures the author tried to ascertain to what extent the later elements of the act would appear without complete expression of the preceding elements. It was found that the later elements were carried on with as much precision as the animal's imperfect mechanical equipment, due to the loss of essential bodily structures, permitted. Recognition of sex arose through trial at copulation. The submissive response of the female, as contrasted with the vigorous response of the male, together with the inability to perform the conjugal act on the latter caused the agressor to relax his clasp and to dismount.

The observations of Craig ('14) on the sexual behavior of the dove reared in isolation bring out many interesting points concerning the adequate stimuli for the initiation of the copulatory act. Male doves, prior to sexual experience with female doves, attempted to perform the sexual act upon the hand of the observer. Copulatory attempts were made also upon such inanimate objects as the perch of the cage and the shoe of the observer. When placed with the receptive female very imperfect coördination in mounting attempts were made prior to the successful execution of the first complete act. One male mounted obliquely across the body of the female and failed totally to effect the union. Following the first series of successful consummations of the sexual act a male showed marked alteration in his general behavior, characterized chiefly by increased agressiveness. An irregularity in the pattern of the copulatory act which persisted for many months was noticed in the case of another male. The preliminary billing that usually precedes copulation was entirely omitted by this male.

Kirkam ('13) studied the breeding habits of the rat. His findings indicate that the male, though present at the time of parturition and for several days subsequently, does not kill the offspring. One pair of young rats mated before either was sixty days of age. This seems to be a very unusual instance of sexual precocity. Observations on the copulatory action of brown rats were reported by Miller ('11). He noted that the females in heat did not allow the young males to copulate. Size and ability to dominate were the determining factors. Frequently adult females were seen chasing about the cage small males which had attempted to copulate. When placed with an adult male the same females permitted copulation, offering little or no resistance. He concluded (from evidence that seems quite insufficient) that bodily odors served as a basis for sexual recognition.

A very elaborate study of the sexual behavior of monkeys and baboons was made by Hamilton ('14). The animals were given far more freedom in their place of confinement than is customary in such studies. Thus reactions closely approximating those found in the natural habitat were observed. Some of the outstanding features of this study are: the great amount of sexual intercourse performed by the males, homosexual tendencies of both males and females, and the use of homosexual behavior on the part of the weaker individuals to divert the attacks of larger males in their attempts at copulation. Under normal conditions of life, the young male, the author believes, does not form habits of masturbation.

Motani ('16) describes the dominating behavior of a male chimpanzee directed toward its cohabitant. When intercourse was desired the male hit the floor of the cage with his hand, whereupon the female approached and assumed the copulatory position before him. Copulation during pregnancy was frequent.

Studies dealing with the reproductive glands as the chief organs exerting a regulatory influence over sexual phenomena are now quite numerous. Although the data of these reports are to some degree relevant to those to be reported in this paper, they can be more advantageously considered in connection with the subsequent study which deals with the internal factors underlying sexual behavior. Such literature will, therefore, be reviewed at a later time.

3. Technique—General

The rats were confined in a uniformly heated room. An extra allowance of whole milk was given to the mothers throughout the period of lactation in order to assure favorable conditions for normal development in the suckling young. Approximately half of the litters were weaned when twenty-one days of age; the other half, at the age of twenty-five days. Although the latter gained weight more rapidly, during the subsequent five or ten days, than those weaned at twenty-one days, this difference in rate of gain was only temporary and so small that it was entirely concealed by the individual variations in rate of growth appearing prior to the age of sexual maturity. Males were separated from females at weaning time. All were segregated for observation in wire-mesh cages which rested on one-half inch of wood shavings contained in galvanized-iron trays. When not in observation cages, all animals except those used in experiments involving isolation, were permitted to mingle freely with others of the same sex and of approximately the same age. Individuals kept in isolation were confined in cages of the dimensions 12 by 8 by 8 inches.

Feeding hours were regular and fell daily between 6.00 and 8.00 p.m. The diet, uniform throughout the period of study, consisted of white bread and whole milk served together in small tin containers during six days of the week. On the remaining day a grain mixture (McCallum diet), made into a mash by the addition of water, was substituted for the bread and milk. Once a week fresh cabbage leaves were added to the above diet. Weight records were taken at five-day intervals or oftener in experiments requiring more detailed records of weight.

The animals whose sexual behavior was observed from day to day were removed from the housing cages to individual observation cages (12 by 8 by 8 inches) from four to six hours prior to the time of observation. The purpose of isolating the animals was to allow time for each to become thoroughly cage-adapted, thereby reducing random cage exploration to a minimum during the period of observation.

In general, the method of studying the sexual behavior of the young animals was systematic observation of normal and operated animals in confinement. Special methods and technique employed in particular phases of the work will be described in detail in connection with the report of experimental data in the following sections of the paper.

THE COPULATORY ACT

The constituent elements of the copulatory act are well coordinated at the time of the initial copulation. No more fundamental problem confronts the student of animal behavior than that of discovering the process by which these constituent elements are integrated into a complex unitary pattern. By the elucidation of this process an important step will have been taken in the analysis of the changes through which elementary activities are being combined and dissolved continually in habit formation throughout the lifetime of living organisms.

A preliminary basis for the study of the integrative process may be established by resolving the copulatory pattern into its chief constituent activities and then ascertaining whether these elements appear in isolated or partially isolated function during the prepuberal life of the young animal or whether they appear for the first time as parts of the complex copulatory pattern. This has been done by observing the prepuberal activity of the young male under natural and experimentally controlled situations. The presentation of these data may be simplified somewhat by considering at the outset the copulatory act of the sexually mature and experienced male. This consideration will furnish an adequate basis for the examination of the prepuberal activities and the initial copulatory act of the young male.

1. *Copulatory act as seen in the mature rat*

One cannot give a detailed description of the male's sexual activities without taking into account the pattern of feminine activity by which it is initiated and toward which it is directed. That is to say, the conjugal act as a whole involves both a masculine and a feminine pattern of activity, the elements of which have a relationship of functional interdependence, and are themselves, acts of a high degree of complexity. The elements of each pattern appear in serial order and are so synchronized that elements of one pattern act in harmony with those of the other. And thus through mutual furtherance they run their courses in the wonderfully complete and well coördinated manner seen in a cross-sectional view of the reproductive process.

When a female is placed into the cage of a *potent* male that has been thoroughly cage-adapted, the latter begins in a few seconds to examine her ano-vaginal zone. Smelling and licking occur irrespective of oestral cycle, and the amount varies with a given individual from day to day. The non-receptive female, thus placed does a variable amount of cage exploration. While doing this, she is followed by the male with his activities directed almost wholly to her. If he is too vigorous in vaginal sniffing, nibbles too deeply in search for parasites, or impedes her progress by playful assaults, she sometimes resists with a back-kick of the hind foot, or by moving into a corner of the cage where she is less accessible to his assaults. The receptive female usually makes a less extensive round of exploration. When approached by the male in the manner described above, she assumes a tense attitude that involves the general musculature of the body and limbs. Frequently this tension is accompanied by slight vibratory movements of the head and shoulders sufficiently general in its distribution to give to the whole body a shivering effect. The shiver may last from one to two seconds. After a moment of smelling or licking, on the part of the male, the receptive female runs forward in the cage a short distance or bruskly shifts her position so that the root of her tail is directly in front of the male. This running movement resembles the quick irregular gallop of the guinea-pig. If the male is sexually aroused by this movement and pursues her across the cage, as is usually the case after she has moved one or more times, she runs only a short distance and halts upon being overtaken by the male and caught in the copulatory clasp. She halts instantaneously when firmly clasped.

Although the responses just described are typical, there are many variations from this type. Some females, persistently, and nearly all observed at the onset of the oestral period, re-act to the vaginal smelling and licking by running wildly about the cage, kicking with the hind foot, and, not infrequently, biting at the pursuer.

In many cases the male begins to copulate within the first minute after the female is placed in the cage. In some instances, however, a variable number of pre-copulatory activities of short duration precedes the act. These activities, for the most part irrelevant in nature, occur in promiscuous order. (They never suggest a type of courting behavior.) The acts appearing most frequently are: nibbling at the head or body of the female, repeated licking and smelling in the ano-vaginal zone, scratching his own body, and momentarily sniffing at the wires of the cage. Rarely, at such times, he stops to lick the penis. The copulatory act, when it does appear, comes with such definiteness and orderly sequence of elements that it stands out in marked contrast and is never confused with this background of promiscuous activities. It is an organized unit of behavior that runs its course with great smoothness when the first element of the series is set into action.

In the act of mounting, the male clasps the sides of the female with his fore-paws encircling her body just posterior to the short ribs. The palmar surfaces of the fore-paws are directed medialward, in a dorso-lateral, lateral, or ventro-lateral position on the female's sides, varying with the size of the female and the girth of the male's fore-limbs. Simultaneously with the clasp, or following so closely that no time interval is discernible, rapid vibratory palpation of the female's sides occurs. To the palpatation, the female responds by depressing the back deeply in the lumbar region. This movement simultaneously elevates the coccygeal region with the hip-joint serving as a fixed pivot of rotation. The elevation of the coccygeal region raises the external orifice of the vagina from the floor of the cage to a height more accessible to the male, and at the same time, throws the axis of the vagina into a plane conforming with the direction of piston movements of the penis when vaginal entrance is attempted.

Following the palpation of the female's sides, which serves as an adequate stimulus for the depression of her back with consequent elevation of the coccygeal region, the male makes a series of rapid movements of the pelvic region which serve to direct the erect penis into and out of the vagina in piston-like manner. With the consummation of the orgasm the palpation and piston movements cease and the male throws himself from the position assumed in mounting by a vigorous backward lunge that clears his body from that of the female by a distance of from three to five or more inches. With the backward lunge he comes to a sitting position with the weight of the body supported on the root of the tail and toes of the hind feet. At the same time the mouth is brought down to the penis which is still in a semi-erect condition. Vigorous licking of the organ follows. After a few seconds licking the organ becomes flacid and is retracted into its sheath and the male comes to a position of rest on all fours where he remains quietly for a short time or engages in minor activities such as nibbling at parasites, scratching the body, or sniffing warily at the female. Smelling and licking in the vaginal zone is seldom repeated after the first two or three copulatory acts.

By way of summarization of the foregoing description the overt pattern of the copulatory act may be broken up into the following elementary acts or groups of activities:

1. Pursuit and mounting.
2. Palpation of the female's sides.
3. On the part of the female, depression of the lumbar region of the back with consequent elevation of the sacro-coccygeal region.
4. Pelvic movements of the male by which the penis is thrust toward the vagina in piston-like manner.
5. Cessation of palpation of female's sides and the backward lunge.
6. Licking of the penis.

The duration of the complete act, from the time of the initial clasp to the backward lunge is usually only a fraction of a second. The time is so brief that one cannot measure it accurately with a stop-watch. In each instance of its appearance, the pattern is strikingly uniform, yet close observation reveals some minor irregularities. A few of these are deserving of mention.

Piston movements by which vaginal entrance is effected do not invariably follow palpation. Sometimes, apparently, this is due to failure in eliciting coccygeal elevation on the part of the female, but again it seems to be due to failure of erection. Evidence of the latter is seen most frequently during a long series of copulations. The number of such instances increases with the number of copulations.

Withdrawal, as a rule, is made immediately upon the consummation of the orgasm, but in the case of males copulating for a somewhat prolonged period of time, there occurs now and then an instance of failure or retarded withdrawal after cessation of piston movements. Prolongations of from one to five seconds have been observed. In these cases the withdrawal is effected by the male alone, with the elimination of the backward lunge, or by the female's jumping forward and slipping from the relaxed clasp of the male. One female on the occasion of tardy withdrawal invariably squealed sharply and turned savagely on the male, striking at his head with her fore-paws or viciously biting at his face and shoulders.

2. Sexual behavior of the young rat

The sexual behavior of approximately fifty young males and three young females was observed in this study under ordinary cage and experimentally controlled conditions. Before considering the data gathered in these observations the methods used in systematically sampling the behavior of certain young males and females will be described.

Two series of systematic observations on young rats were made during their prepuberal development and for a short time thereafter. These series differ somewhat in type and serve to supplement each other. In the first series 15 males and 3 females were observed from the age of thirty days to the age of somatic maturity. The group consisted of the following animals: 6 normal males; 3 normal females; 2 blind, 4 anosmic, and 3 castrated males.

The fifteen males were confined in a large cage (18 by 20 by 30 inches) while not in their individual observation cages. The females were kept with a group of from two to four females of the same age in a smaller cage (10 by 16 by 14 inches). Daily all were isolated in individual cages for a period of from four to six hours prior to the time observations were made. Between the hours of 5.00 and 8.00 p.m., when the animals are normally very active, a female—non-receptive[1] as a rule, but receptive when available—was placed in the cage with a male. The young animals were observed individually, upon the introduction of the female, for periods varying from five to fifteen minutes daily, or longer if the activity of the young animals made a prolonged period of observation desirable. Notes pertaining to the general types of activity, the aggressiveness or lethargy of male or female, etc., were made. Also points of a more specific nature were looked for, such as: smelling and licking the ano-vaginal zone; attempts at sucking; nibbling at the sheath of the penis; unsheathing, licking and manipulating the penis; rhythmic extrusion and retraction of the penis in the sheath; mounting and palpation of the female sides while in the copulatory position; playful attempts at copulation prior to the age of sexual maturity.

---

[1] The term non-receptive is used to describe females that would not copulate—females not in heat.

In the second series of observations the method was varied to bring out more details on certain points not revealed in the previous study. In the first series quantitative data concerning the kinds of activities and their duration were not secured. Furthermore, there was no control over the activities aroused by mingling with other animals of the same age while not under observation.

In the second series 8 animals, 6 males and 2 females, all of the same litter, were used. It was a well nourished litter and the young were able to subsist on a bread and milk diet at the age of twenty days. When twenty-one days of age the young were weaned and isolated in individual cages where they were kept during the entire period of study. Under these conditions they had no opportunity to mingle with other animals, except while with the adult during the period of observation. On alternate days the behavior of each animal was studied and records were made which gave the type of activity and its duration in each minute of a twelve-minute period.

A simple scheme for recording the behavior was devised. All the types of activity that had been observed during the first study were listed. Certain acts of a similar nature were thrown together in order to reduce the number of categories as much as possible, yet keeping separate all acts of a doubtful or definitely sexual nature. Obviously this catalogue is devoid of logical arrangement and the range of its usefulness is limited wholly to the needs of the problem at hand.

When the list of categories was satisfactorily arranged and pruned down to workable proportions a number was given to each of the items; this was to be used later as a symbol for that item. Then the categories and the numbers that stood for each were thoroughly memorized and tried out in practice for a short time upon other animals. With stop-watch in hand the observer recorded chronologically in one column of the record blank the time of incidence of each activity and in a column beside it the appropriate number to denote the category into which it fell. Obviously the time at which each new act began marked the end of the old act.

From these records the exact duration of every act during each minute of the twelve-minute period was computed. This gave a record of the type of action, its duration, and its relation to other activities in the twelve-minute period. The table that follows gives the catalogue of activities used, together with a code-form or abbreviation that will be used in the tabular reports of the data from the observations.

The young male rat, whether mature or immature, if thoroughly tame and cage-adapted, usually loses no time in approaching the female when she is introduced into the cage. Almost invariably, in these observations, he was at her side before all her feet were implanted on the floor of the cage. He proceeds in a direct and thoroughgoing manner to explore the female by sniffing and licking, nibbling and nosing her body in various places—activities which readily cause the receptive female to betray, by actions easily recognized by the experimenter, her condition of receptivity. Evidence of sexual excitement is manifested by the male, as a rule, in the first five or ten minutes after the female is placed in the cage or not at all. Hence for practical purposes, it may be assumed that if the animal under observation does not show signs of excitement during the first five or ten minutes, providing he has thoroughly explored the female during that time, he will not ordinarily show signs in from one-half to one hour or more of observation. This practical rule is founded on numerous observations for periods lasting from one-half to one hour, on over fifty young males used in the various phases of this study.

TABLE 1

	LIST OF CATEGORIES USED IN RECORDING THE BEHAVIOR OF YOUNG MALE WITH ADULTS	ABBREVIATED CODE
1.	Nibbling at head, neck, body and limbs from any position; sniffing and nosing or licking at any region of female's body other than elbows and vaginal and anal region	Nibbling
2.	Smelling or licking in ano-vaginal region..................	Licking
3.	Exploring cage, nibbling at foreign matter in cage, climbing about cage, and running in cage not involving pursuit or escape from female............................	Cage explor.
4.	Following female as she moves about cage with head in close proximity....................................	Following
5.	Idle, resting—not asleep................................	Idle—awake
6.	Idle, asleep..	Idle—asleep
7a.	Wrestling—young male the aggressor....................	Wrest.—young
7b.	Wrestling—adult female the aggressor..................	Wrest.—adult
8a.	Fighting—young male the aggressor.....................	Fight.—young
8b.	Fighting—adult female the aggressor...................	Fight.—adult
9.	Nibbling, kicking, or scratching own body, *other than penis*..	Scratching
10.	Licking penis, or *young* female licking external genitals...	Lick.—penis
11a.	Female sniffing, licking, or nibbling body of male other than genital organs—male passive....................	F. lick. Body
11b.	Female sniffing, licking, or nibbling genitals of male......	F. lick. Genit.
12.	Reciprocal sniffing, licking, or nibbling genitals..........	Recip. lick.
13.	Fear response, in which male assumes definite physical attitude or pose..	Posing
14.	Mounting, involving clasp and palpation of female's sides	Mounting
15.	Miscellaneous..	Miscel.
16.	Fear response of male in which pose is not assumed. Remains stationary or moves about cage...............	Caution
17.	Nursing or attempts at nursing.........................	Nursing
18.	Act of copulation......................................	Coition
19.	Smelling or licking right elbow (hair saturated with aqueous solution of pituric acid)............................	Rt. Elbow
20.	Smelling or licking left elbow (control)..................	Lt. Elbow

By this method of observation, the behavior of young males with the female has been sampled from day to day throughout the period of development from weaning to sexual maturity. It is believed that the samples, taken collectively, give a very fair picture of the general nature of the activity of the young rat in the company of the female at various ages prior to sexual maturity. It, will, therefore, serve as a tentative basis for the consideration of permature sexual behavior.

A. Prepuberal behavior. Tables 2 to 11 give the data for each of the eight rats used in the study. Rats 50 and 54 were observed daily. On alternate days an adult male was substituted for the female. The other six animals were observed on alternate days, and with females only. The data for two consecutive observations have been combined and averaged in order to condense the results somewhat, thereby giving a more compact picture of the types of behavior to which attention will be called. The numbers give the time in seconds spent by each rat during twelve minutes doing a particular act or class of acts grouped under a heading of the category.

For the purpose of briefly considering the relation of the foregoing prepuberal activities to the copulatory act they may be thrown into two groups: (*a*) A group of non-sexual, or acts that are obviously unrelated to the copulatory act; and (*b*) a group of acts that appear to be connected with the copulatory act but are really not so connected. Under these headings the chief facts brought out in the two series of observations may be considered.

a. Non-sexual activities. The young rat, twenty-one days of age, gives attention to the adult female as soon as the latter is placed in the cage. It approaches without fear and procedes to explore such parts of her body as are within reach. From three to five days later it climbs upon her back, if she sits quietly in the cage, and extends the general exploration to the back, neck and top of her head. Sniffling in the region of the mammary glands is seen occasionally at or a few days after the age of twenty-one days, but only rarely after twenty-five days. The greater part of the time during the first five to ten minute is spent in nosing about the head of the female, licking her body, and searching for parasites (*Nibbling*, tables 2 to 11.) This holds true for all ages from the time of the first observtions to the last. While

TABLE 2

Analysis of behavior of rat 50, male, in presence of female during 12 minutes daily from the age of 21 days to the age of 81 days. Copulated at age of 74 days. Numbers in the table represent time in seconds spent at each type of activity

AGE IN DAYS	NIBBLING	LICKING	CAGE EXPLOR.	FOLLOWING	IDLE—AWAKE	IDLE—ASLEEP	WREST.—YOUNG	WREST.—ADULT	FIGHT.—YOUNG	FIGHT.—ADULT	SCRATCHING	LICK. PENIS	F. LICK. BODY	F. LICK. GENIT.	RECIP. LICK.	POSING	MOUNTING	MISCEL.	CAUTION	NURSING	COITION	RT. ELBOW	LT. ELBOW
21–23	542½	3½	79½	2							17½		56½	12½				6					
27–29	572	11½	83	7½	3½	5½					12		10	6								9	
31–33	613		69	13							11		7	3	1½							2½	
35-37	576	11	21½	15						8½	1								52½			34½	
39–41	658	17	37									5										3	
43–45	648½	22½	15								10	10	2½	6								6	
47–49	653	21	22	4								10	1	9									
51–53	601½	27	38½		30						16½	4										2½	
55–57	471	11½	11½	2½	128½						2½	30	62½										
59–61	588½	42½	56½	5			10				14	3											
63–65	563	37½	35	27½	10					5	13	11½	1½	1					15				
67–69	241	19½	40	217½	25		5			70		3½	6	2½					90				
71–73	448	30	184	10	28						20												
75–77	467½	30	114½	77½	25						3		2½										
79–81	469	45	189½	2½							11½	2½											

TABLE 8

Analysis of behavior of rat 50 in presence of male during 12 minutes daily from the age of 31 days to age of 77 days. Copulated at age of 74 days. Numbers in the table represent time in seconds spent at each type of activity

AGE IN DAYS	NIBBLING	LICKING	CAGE EXPLOR.	FOLLOWING	IDLE—AWAKE	IDLE—ASLEEP	WREST.—YOUNG	WREST.—ADULT	FIGHT.—YOUNG	FIGHT.—ADULT	SCRATCHING	LICK. PENIS	F. LICK. BODY	F. LICK. GENIT.	RECIP. LICK.	POSING	MOUNTING	MISCEL.	CAUTION	NURSING	COITION	RT. ELBOW	LT. ELBOW
31–33	264	4½	33½		2½						25		1½									6	
35–37	666	18	27									4	5										
39–41	607	26	3	5							17½	1½	28	19								13	
43–45	523	24½	37		7½					11	3	2½	47½	16	8				40				
47–49	597½	13½	60½		18½						8½	4½		12	5								
51–53	486	19	10	5						4	13½		6½	4		150			22				
55–57	266½	16	22½	103½	12½					4			16½	19	12½	163			124				
59–61	464½	26	41	103½	12½					3½	5		9	21	12½				12½			9	
63–65	319	21	53							1			3½	37		236			49½				
67–69	42½	2½	5½	59½	332½					4½		8		5					260				
71–73	152½			76	5						16			6½		300½			164				
75–77	11			90									2	16					592				

TABLE 4

Analysis of behavior of rat 54, male, in presence of females during 12 minutes daily from age of 21 days to the age of 76 days. Copulated at age of 75 days. Numbers in the table represent time in seconds spent at each type of activity

AGE IN DAYS	NIBBLING	LICKING	CAGE EXPLOR.	FOLLOWING	IDLE—AWAKE	IDLE—ASLEEP	WREST.—YOUNG	WREST.—ADULT	FIGHT.—YOUNG	FIGHT.—ADULT	SCRATCHING	LICK. PENIS	F. LICK. BODY	F. LICK. GENIT.	RECIP. LICK.	POSING	MOUNTING	MISCEL.	CAUTION	NURSING	COITION	RT. ELBOW	LT. ELBOW
21–24	524	2⅓	80	6⅓	20⅓						59		20	1				6⅓					
26–28	559⅓	1	106½	1½		16⅓					14⅓		4	12						2⅓		2	
30–32	440	9	165	20⅓							26⅓		17	10⅓								31½	
34–36	568	17⅓	33	7⅓		6				10				2					66⅓	2⅓		7	
38–40	597⅓	15⅓	75																27⅓			4⅓	
42–44	519⅓	24⅓	89⅓		11⅓						29⅓	7⅓	2⅓									29⅓	6
46–48	583	39	34									5	47	7	5								
50–52	587	25	91								4⅓	2⅓	10										
54–56	208	18	95	157	83					18	10		8	13					110				
58–60	463		38⅓								11												
62–64	477⅓		152								28	17½		4								2⅓	
66–68	584	33	85								5											13	
70–72	433⅓	35⅓	205⅓	7⅓						1⅓	3⅓	12½	6	4⅓		2⅓			7⅓				
74–76	214⅓	15	149⅓		43⅓						12⅓								285				

TABLE 5

Analysis of behavior of rat 54 in presence of males during 12 minutes on alternate days from the age of 33 days to the age of 77 days. Copulated at the age of 76 days. Numbers in the table represent time in seconds spent at each type of activity

AGE IN DAYS	NIBBLING	LICKING	CAGE EXPLOR.	FOLLOWING	IDLE—AWAKE	IDLE—ASLEEP	WREST.—YOUNG	WREST.—ADULT	FIGHT.—YOUNG	FIGHT.—ADULT	SCRATCHING	LICK. PENIS	F. LICK. BODY	F. LICK. GENIT.	RECIP. LICK.	POSING	MOUNTING	MISCEL.	CAUTION	NURSING	COITION	RT. ELBOW	LT. ELBOW
33–35	464½	4½	89½	12½	12½						20		1½	5						15		95	
37–39	391	30	196	43							6		21	33									
41–43	502½	18½	162								21		13½									2½	
45–47	568	19	77								10	18		28									
49–51	451½	33½	146				5				2	20	12	50									
53–57	367½	26	57	27½	119		5	5		3½	28½		9	15	3	6			48				
59–61	555½	26	92½				2½					7½	5½	26½	4								
63–65	155	27	2							5			14	12		417			94				
67–60	44	22½	163	140½	42½					5			12½	7½		7½			275				
71–73	62½	12½		269	165½						9½		1	20		180							
75–77	15½	1		45								1	7½	8½		15			626½				

TABLE 6

Analysis of behavior of rat 51, male, in presence of females during 12 minutes of alternate days from the age of 21 days to the age of 89 days. Became ill at that time. Experiment discontinued before copulation. Numbers in the table represent time in seconds spent at each type of activity

AGE IN DAYS	NIBBLING	LICKING	CAGE EXPLOR.	FOLLOWING	IDLE—AWAKE	IDLE—ASLEEP	WREST.—YOUNG	WREST.—ADULT	FIGHT.—YOUNG	FIGHT.—ADULT	SCRATCHING	LICK. PENIS	F. LICK. BODY	F. LICK. GENIT.	RECIP. LICK.	POSING	MOUNTING	MISCEL.	CAUTION	NURSING	COITION	RT. ELBOW	LT. ELBOW
21–23	516	2½	75		7½	11					41½		34	200½				12					
25–27	440½	2½	168½	19	57						23½			7								2	
29–31	519½	9	90	½							24		1									76	
33–35	652½	22½	22½								10			5½						5			1
37–39	657	10½	27½								8½											15½	
41–43	527½	25	132								6											29½	
45–47	614½	19½	76	5							2½	2½											
49–51	641½	54	14								5½		2½	2½									
53–57	619½	25	1		42½						2		22½									7½	
59–61	655½	17½	1								4½		31½										
63–65	518	21½	63½								6											111	
67–69	695	8	2																			15	
71–73	372½	39	7½	11½	196½					4½	4		2½	2					80				
75–77	401½	13	3½	12½	90					8½	13	22		8	87½				60½				
79–81	162	2	38	36½	48½					13	70½		5½	8½		41½	23½		272½				
83–85	342½	5									20			12½					340				
87–89	35	7		46½	296½					17½	49	65	5	17½		62			118½				

TABLE 7

Analysis of behavior of rat 52, male, in presence of females during 12 minutes of alternate days from age of 21 days to age of 87 days. Copulated at age of 85 days. Numbers in the table represent time in seconds spent at each type of activity

AGE IN DAYS	NIBBLING	LICKING	CAGE EXPLOR.	FOLLOWING	IDLE—AWAKE	IDLE—ASLEEP	WREST.—YOUNG	WREST.—ADULT	FIGHT.—YOUNG	FIGHT.—ADULT	SCRATCHING	LICK. PENIS	F. LICK. BODY	F. LICK. GENIT.	RECIP. LICK.	POSING	MOUNTING	MISCEL.	CAUTION	NURSING	COITION	RT. ELBOW	LT. ELBOW
21–23	641	4	54½		7½	7½					3½	1						1					
25–27	620	9½	31								4		3½	4								48	
29–31	624½	6	25½				2½				17½		16									28	
33–35	507½	17	104½	17						7½	30½			3½					30	1½		1	
37–39	506½	8½	136		25						43												1
41–43	544½	40½	74								61												
45–57	574	28			5		7½			6	20	21½	1	3					2½				
49–51	562	44	76½								25	12½											
53–55	524	45½	115½								18	3½	5	3½								2½	
57–59	558	42	38								60½	13½	8										
61–63	644½	9	17½								2½									46½		46½	
65–67	615½	23½	51½							2½	27												
69–71	437	53½	107	14		17½					46½	29½										15	
73–75	407½	39½	167½	2½	5			7½			53½	24½	12½										
77–79	451½	40	143	6½	30						38	7½		3½									
81–83	271	33	123								288		5										
85–87	561	60½	32								26	10½	5										

TABLE 8

Analysis of behavior of rat 53, male, in presence of females during 12 minutes of alternate days from age of 21 days to age of 87 days. Became ill at that time. Experiment discontinued before copulation. Numbers in table represent time in seconds spent at each type of activity

AGE IN DAYS	NIBBLING	LICKING	CAGE EXPLOR.	FOLLOWING	IDLE—AWAKE	IDLE—ASLEEP	WREST.—YOUNG	WREST.—ADULT	FIGHT.—YOUNG	FIGHT.—ADULT	SCRATCHING	LICK. PENIS	F. LICK. BODY	F. LICK. GENIT.	RECIP. LICK.	POSING	MOUNTING	MISCEL.	CAUTION	NURSING	COITION	RT. ELBOW	LT. ELBOW
21–23	546	3	83½		7½						61½							18½					
25–27	577	11½	69½	2½	26½		1½	1			9			2½						6½		12½	
29–31	632	10½	59								11											7½	
33–35	514	15	183½		2½				3													2½	
37–39	564	26	63½		16½					5	10	6	3½	1								24½	
41–43	517	30	99½	11	53½						9												
45–47	466½	23	156½	2½						10	16½		12½	20	10				2½				
49–51	300½	53	54	29	123					2½	60½								32½			65	
53–55	437½	32½	80½	7½	82½						7	10	48½	13									
57–59	560	35½	63½		2½						9		10½	4								35	
61–63	547	13	115								45												
65–67	461	31½	155½	41							18											13	
69–71	544	44½	114½								9	8											
73–75	470	41½	73½	63½	6½						23	13½	2½									30	
77–79	226	23½	13½	68						4	13½		1	4					329½			37	
81–83	335	11½	132½	43½	31½						5		140										

TABLE 9

Analysis of behavior of rat 55, male, in presence of females during 12 minutes of alternate days from the age of 21 days to the age of 85 days. Copulated at age of 85 days. Numbers in the table represent time in seconds spent on each type of activity

AGE IN DAYS	NIBBLING	LICKING	CAGE EXPLOR.	FOLLOWING	IDLE—AWAKE	IDLE—ASLEEP	WREST.—YOUNG	WREST.—ADULT	FIGHT.—YOUNG	FIGHT.—ADULT	SCRATCHING	LICK. PENIS	F. LICK. BODY	F. LICK. GENIT.	RECIP. LICK.	POSING	MOUNTING	MISCEL.	CAUTION	NURSING	COITION	RT. ELBOW	LT. ELBOW
21–23	434	2	202		42½	20					11		2½	5				1					
25–57	513	10	170		5						10½		1							6½		4	
29–31	519½	18	164½								7			1						2½		7½	
33–35	455	10	176		2						12	2½										63½	
37–39	549½	16½	133½							4½	3½		12½										
41–43	491	16½	193½								4											15	
45–47	415½	30	259½		5						4½		4½		1								
49–51	564	48	90½		5						12½												
53–55	537	20	119		11						24½	5	3½										
57–59	537	32	52½		23						16	39										20½	
61–63	475	30½	16		20					5	27	41½	2½				102½						
65–67	660	33	5										10	12									
69–71	517	20½	7½								84½	79		11½									
73–75	311½	33	275½	14							35½	50½											
77–79	376	53	33							6	123½	30½							98				
81–83	80	24	50	104	201					2½			1						257½				
85	2	12		46									30						630				

TABLE 10

Analysis of behavior of rat 56, female, in the presence of females during 12 minutes of alternate days from the age of 21 days to the age of 79 days. Experiment discontinued at that time. Probably sexually mature. Numbers in table represent time in seconds spent at each type of activity

AGE IN DAYS	NIBBLING	LICKING	CAGE EXPLOR.	FOLLOWING	IDLE—AWAKE	IDLE—ASLEEP	WREST.—YOUNG	WREST.—ADULT	FIGHT.—YOUNG	FIGHT.—ADULT	SCRATCHING	LICK. EXT. GENIT.	F. LICK. BODY	F. LICK. GENIT.	RECIP. LICK.	POSING	MOUNTING	MISCEL.	CAUTION	NURSING	COITION	RT. ELBOW	LT. ELBOW
21–23	558½	3	76		7½						32				12			31					
25–27	558½	3½	122	3							20			17						5		1½	
29–31	406	12	116	62½				27½			49			8½		2½			30			6	
33–35	581½	4½	78	32½						1½	16½	2½		2								1	
37–39	556½	7	119½						1½		31	2½		2									
41–43	539	6	48								19	7										47	
45–47	609½	19½	62½								28½												
49–51	369½	16½	56	17					32½		11	7½	5	9		2½			19½				
53–55	513½	24	90½		7½		42½	2½			2½		16½	7					13½				
57–59	508	14	115				5				19											59	
61–63	600	14½	43								17½											55	
63–67	512½	11	134½								30½		1½									30	
69–71	244½	27½	147½	100	2½				7½		9		4	7½					170				
73–75	72	9½	86	48½	42½						1½								80				
77–99	84	15	14	420	60						11	2							114				

TABLE 11

Analysis of behavior of rat 57, female, in the presence of females during 12 minutes of alternate days from the age of 21 days to the age of 57 days. Experiment discontinued at that time. Probably sexually mature. Numbers in table represent time in seconds at each type of activity

AGE IN DAYS	NIBBLING	LICKING	CAGE EXPLOR.	FOLLOWING	IDLE—AWAKE	IDLE—ASLEEP	WREST.—YOUNG	WREST.—ADULT	FIGHT.—YOUNG	FIGHT.—ADULT	SCRATCHING	LICK. EXT. GENIT.	F. LICK. BODY	F. LICK. GENIT.	RECIP. LICK.	POSING	MOUNTING	MISCEL.	CAUTION	NURSING	COITION	RT. ELBOW	LT. ELBOW
21–23	568	11½	57½								39		33					11					
25–29	593½	10	86	15½	2½						5									1		6½	
29–31	636	7	31								17											29	
33–35	599	9	53½		55						1											2½	
37–39	641	10½	50	2½							14½												
41–43	617	20	6								22½		5	5								7½	7½
45–47	627	19	2½	16	20					7½			10½	2½					15				
49–51	293	28½	40		20					13½	14½		21½	5		280							
53–55	479	15	86	44	7½		20			6	1½		5	6					43				
57–59	379	12½	10	145	21					4	1½		7½			10½			129				
61–63	497½	29	106½	62							13½		9									2½	
65–67	611	9	64	15							8			3								10	
69–71	527	20	28½	109						6½	5	5	5	1½					12½				
73–75	633	16	63½								7½												

nosing about the body of the female the young animal discovers the chief sources of secretions and excretions. Both males and females begin to smell in the vaginal region when twenty-one to twenty-three days of age (*Licking*, tables 2 to 11).

The smelling lasts for only a few seconds until approximately twenty-eight to thirty days of age, when the individual periods of smelling lengthen somewhat and the total amount of smelling during an observation is also increased by only a small amount during the remainder of the prepuberal period. At the age of thirty to thirty-five days, smelling is begun within a few seconds after the female is placed in the cage.

The amount of time given to cage exploration is fairly constant at various ages. This appears for the most part during the last half of a ten to twelve minute period of observation. After the young rat has thoroughly explored the female her presence has less stimulating effect on it, hence it is more easily distracted by stimuli coming from other sources—noises in the room, odors from the walls of the cage, loose shavings to be nibbled, feces, etc.

Frequently the female, after making a tour of the cage, gives her attention to the young in the cage for a short time. She nibbles and licks his body and smells his genitals. This is done at every age of the young male. The active females most frequently stop to smell the genitals of the young. Sometimes the two are seen smelling each other's genitals simultaneously. This occurs most frequently when an adult male is placed with the young animal.

Attempts at nursing were seen during a few observation-periods after the young animals were weaned. These attempts consisted chiefly of sniffling and nibbling about the mammary glands.

In no case was a young male seen to launch a vicious attack on an adult female. Being attacked, however, the young animal sometimes defended himself. The adult female and adult male showed practically no inclination to attack young animals under forty days of age. Then, and until the observations were brought to an end, the attacks of the adults were frequent.

If attacked by a much larger animal the young rat seldom resists by assuming the aggressive. He takes up a defense pose which enables him to guard against the attack of the aggressor and indicates to the latter that no counter attack from him is to be expected. Sometimes after the adult ceases pummeling the young animal, the latter holds the defense pose for several minutes (*Posing*, tables 2 to 11). Particular attention is called to the amount of posing done by the young animals in company with adult males (tables 2 and 3). Contrast with tables 4 and 5. The adults show increased tendency to maltreat the young after the latter have reached the age of forty to fifty days (tables 3 and 5). Item 16 which is another phase of the defense response, characterized by cautiously avoiding the adult, shows that the attacks of the adult cause responses which carry over from day to day. Not infrequently the young animals showed this fear response, although no attack on the part of the adult had been made or threatened during that period.

Wrestling is initiated both by the adult and by the young. It was an activity of daily occurrence in the case of the first group of twenty-three animals; they were allowed to mingle together while not in the cages for observation. The eight animals of the second group, which were reared in almost total isolation seldom attempted to wrestle with the females. It appears that this activity acquires the characteristics commonly seen in the play of young rats only through experience.

The amount of time spent in following closely behind the adult without actually smelling or nibbling depends somewhat upon the general activity of the adult. Most animals continue their smelling and nibbling while the adult moves about the cage, but occasionally one follows without actually touching the adult's body.

In a subsequent chapter the purpose of the experiment involving the placing of a weak solution of pituric acid on the left elbow of the female will be discussed at greater length. Attention is called at this place to the fact that all young animals discovered the oderiferous substance at once. The amount of smelling in this region greatly exceeded that of the vaginal zone for several days, but gradually the amount ceased to increase and eventually decreased; finally this region was not smelled by some animals at all during the periods of observation (*Lt. Elbow*, tables 2 to 11).

b. Acts that appear to be related to the copulatory act. At all ages the young animals stop any activity in which they are engaged to bite and scratch parts of their bodies. The amount of scratching varies from day to day and shows no regular tendency to increase or decrease at particular ages. Associated with scratching of the body is the nibbling of the external genitals which, in the case of the males, eventually comes to be chiefly the licking of the penis. The amount of licking of the genitals increases in amount from the age of thirty-five to forty days and is seen frequently thereafter until the age of puberty is reached. Casual observations lead to the conclusion that it is continued throughout the period of potency of the male. In the case of rat 52, a well developed male for his age, about 2 mm. of the glans penis was seen protruding from the prepuce at the age of forty-two days while the male was vigorously licking and nibbling the sheath, using his fore-paws at the time to manipulate the organ into positions favorable for licking. With age the tendency for the penis to protrude while licking becomes greater because of development in size. Thus, accidentally at first, the tongue is brought into contact with the sensitive glans penis. The stimulating effect of licking probably causes the act to be repeated and to become habitual. Whether or not this act may be considered a form of masturbation in the rat is an open question. It is well known that the tongue and oral mucosa in contact with the penis of man is capable of arousing the reflexes concerned with ejaculation. (Ellis, vol. 11.) In the case of the rat, however, no case of orgasm has been discovered as a result of the licking of the organ, but the difficulties of detecting the orgasm are such that one cannot be sure that it is not effected. The vigorous movements of the pelvis seen in some instances of the licking and the use of the fore-paws to manipulate the sheath suggest that these acts aid in producing the maximum stimulation of this organ while licking is in progress. No evidence was found which indicated that it aids in the initiation of the first copulatory act.

With respect to young animals it has been suggested that many of the play activities anticipate the larger acts that are to be performed by the adult for the preservation of self or the species. Groos ('95) interprets the mounting seen in some animals in infancy as anticipatory practice in the reproductive function. Careful watch was kept for this in the young male rat, but no mounting of the kind done by copulating males or males during the period of pre-copulatory activity was noticed. Two male rats that were *over seventy days of age* which had not had sexual congress were observed, however, to mount cage-mates in the definitely sexual manner, and attempt a complete copulatory act. Small ('99) speaks of the playful sexual activities of rats under thirty days of age. Our own study does not substantiate his observations. When receptive females were placed with the young males the latter showed no definite sexual excitement until approximately 70 days of age. Prior to that time the smelling of the vaginal region of receptive females was sometimes more extensive than with normal females, but that may be accounted for by the tendency of young rats to smell at any new odors that are introduced. The secretions of the vagina at the time of the oestrum give rise to new olfactory stimuli to be examined, hence the periods of smelling when females in heat are introduced into the cage are somewhat longer.

B. *Initial copulatory act.* The initial copulatory act of the young male resembles that of the experienced adult so closely that differences are not easily discerned. Using as a background the descriptive account (pages 101–105) of the copulatory act of the adult, one can get a fairly complete picture of the initial copulatory act of the young male by considering the differences between the two.

a. Copulatory act of the young male contrasted with that of the adult. Two kinds of differences between the act of coition of the adult and the young have been found occurring with a fair degree of regularity. The first consists of differences that arise from structural limitations—size, girth of forelimbs, and general bodily vigor; the second, of differences which result from the shunting of sexual behavior by fear responses or differences that appear to arise from slightly incomplete coördination of the elements of the complex mechanism involved in the copulatory act. Differences of the first type, being relatively unimportant for this study, will be passed over with only brief remarks as to their nature.

Limitations in the size of the male and the girth of his fore-limbs cause a slight difference in the placement of the fore-paws on the body of the female as he stands in the copulatory position. Difference in strength of the fore-limbs results in palpation less vigorous than that of the adult. The palpation suffices, nevertheless, to elicit the necessary coöperation of the female. Frequently the backward lunge of the young is greatly reduced in force or even eliminated entirely—the male slipping smoothly from the mounting position.

The second group of differences between the experienced male and the novice needs more careful consideration for it embraces factors that are concerned with the initiation of the copulatory response. During the tests for copulation in young males fear responses, aroused by an attack or threatening attitude of the female, caused the male to move as far from her as the space in the cage permitted. There he remained quietly but on guard against further assault. These responses sometimes last only a few minutes, but in other cases more than an hour. Young rats which had recently been pummeled or bitten severely by adult rats during the daily observation periods sometimes exhibited fear responses to the quick movements of the receptive female in the cage. Such fear responses were sometimes aroused by very docile females which were responding to the male's nosing and licking with the spasmodic jumping that characterizes the female in heat. Evidently the young male does not readily differentiate these quick responses from the aggressive movements of attack, and therefore, responds in a manner appropriate to the avoidance of punishment rather than in a manner appropriate to effecting copulation. Fear responses of this type are seldom seen in the adult male, and they quickly disappear in the young after copulatory experience. In this connection it will be recalled that, according to Miller ('11), the female brown rat chased the young males about the cage and would not permit copulation, but when placed with large males she became quite submissive.

The sexual aggression of the young male is thwarted by slight resistance of the female more readily than is that of the adult male. Females which back-kick, and run wildly about the cages are less often subjugated by the young male. Likewise those that are extremely lethargic are less often forced into positions favorable for copulation. Although this is due, in part, to a difference in strength of the mature and immature male, it is due in greater part to a difference in aggressiveness. A change in this respect comes on rapidly after the act of coition has been initiated. Craig ('14) reports a similar change in the behavior of one of the doves.

Another kind of difference centers about the appearance of the elements of the copulatory act in a stage of slight disorganization. Illustrations of this are common in the copulatory attempts of the inexperienced male just prior to the first successful copulatory act. These elements may consist of mounting with or without definite clasp, mounting and palpation of the female's sides, and rarely, mounting and palpation of her sides with feeble pelvic movements that do not effect vaginal entrance. In the latter case further attempts to repeat the act are not made at once, contrary to the general rule in the case of the experienced male. The frequency of occurence of these partial attempts has been calculated for thirty young males from the records of their behavior with a female just prior to sexual experience. Sometimes the elements which appeared in dissociated or only partially integrated patterns anticipated the complete act by only a few minutes or an hour or two. In other cases they appeared several days earlier. These records show that of the thirty rats:

Six mounted with firm clasp, but with no other elements of the copulatory act involved, prior to the first complete act of coition.

Fourteen mounted and palpated the female's sides, but did not make pelvic movements.

Eight animals performed the complete act without previously performing any of the partial acts given above.

The appearance of these dissociated elements is not confined to the young animal alone; it is sometimes seen in the adult as well. The difference is one of relative frequency only.

Following the first period of copulation the young animal is less discriminating in the mounting of other animals than the adult. He mounts without regard for sex or condition of receptivity. Here again the difference is largely one of degree characterized by persistence in mounting attempts, for the adults also have been observed to mount non-receptive females and males at various times after a period of copulation was brought to an end.

In two instances young males performed the first sexual act while mounted at the head end of the female and with the forelimbs clasping the head and shoulders rather than the sides. The pelvic movements were directed toward the face in these cases.

Licking the penis is, so far as observations in this study go, an invariable element of the complete copulatory act providing vaginal entrance has been effected. In the case of the young male the licking is oftimes omitted at the completion of the first sexual act. This probably, is due to incomplete erection and failure to make vaginal entrance.

b. The age of functional sexual maturity and the strength of the copulatory impulse. The age at which copulatory ability normally appears has never been determined under sufficiently controlled conditions to establish a reliable norm. Kirkham ('13) reported that a pair of rats bred prior to the age of sixty days. Hewer ('14) considered rats of seventy days of age as sexually mature, for at that time she was able to find spermatazoa in the epididymis. My own observations show, however, that copulatory ability does not run exactly parallel to production of spermatazoa. Therefore, her criterion is not a reliable index of the age at which copulatory ability appears.

In table 12 are given data bearing on the age at which the first sexual act appeared in seventeen normal rats reared under conditions as nearly uniform as possible. The age and number of minutes given to testing each rat prior to the appearance of

TABLE 12

In this table are given the ages at which tests for copulation were made on 17 normal rats, the number of minutes tested at various ages prior to the first copulatory act, the age at the time of the first copulation, and weight of the animal at the time of first copulation. Tests were given in periods of from 6 to 20 minutes in length. Minutes are designated by the symbol ′ and seconds by the symbol ″. The test period in which copulation took place is italicised.

RAT NUMBER	AGE	MINUTES TESTED	AGE	MINUTES TESTED	AGE	MINUTES TESTED	AGE	MINUTES TESTED	AGE	MINUTES TESTED	WEIGHT
											grams
9	67	16′	77	*2′ 54″*							147
10	70	8′, 6′	75	6′, 6′, 8′	82	6′, 6′, 8′	88	6′, *1′ 47″*			153
11	118	*27″*									
12	84	7′, 6′	94	*1′ 04″*							
13	70	10′	76	*1′ 29″*							158
14	74	8′, 6′	79	6′, 6′, *2′ 02″*							135
15	71	6′, 8′	76	6′, 8′, 6′, 6′	83	*4′ 30″*					125
16	75	6′, 6′, 6′	82	6′, 6′, 6′	88	6′, 6′, 6′	96	6, *3′ 20″*			
17	70	6′, 6′, 6′	82	*15″*							
18	64	*7′ 9″*									123
50	57	8′, 10′, 12′	65	10′, 8′	74	*1′ 50″*					145
52	57	8′, 10′, 8′	65	10′, 10′	69	15′, 10′, 5′	74	8′, 11′	76	8′, 12′ 85da. 8′, *1′10″*	157
54	57	8′, 14′, 12′	65	8′, 12′, 11′	69	8′, 12′, 10′	74	8′, 12′	76	*3′ 20″*	140
55	57	8′, 12′, 10′	65	8′, 12′, 10′	69	8′, 12′, 10′	74	8′, 12′	85	*8′ 45″*	139
19	72	8′, 10′	78	8′, *2′ 05″*							142
20	71	10′, 9′	77	*4′ 20″*							135
21	71	8′, *4′ 55″*									137

the first act are presented together with the weight of each rat at the time of the first copulation. The data given in that table show that the earliest age at which copulatory ability was demonstrated was sixty-four days. Probably the normal age falls somewhere between seventy and eighty-five days in the case of well nourished rats.

Table 13 presents data bearing on the amount of copulation young rats are capable of doing at the time copulatory ability is first manifested. This group of males consists of normal males, semi-vasectomised males, and males with one or more receptors removed. No data are available to indicate how frequently vaginal entrance is not effected, or an orgasm is not reached. The number of copulatory attempts of the young animal following the initial copulation approximates that of the well nourished adult animal.

TABLE 13

Copulatory records of young males during periods of time varying from 60 to 30 minutes following the initial copulation. The age of the copulating animal is indicated. Also the condition of the rat—normal, blind, anosmic or with ductus deferens of one testicle ligated—is stated.

RAT NUMBER	AGE IN DAYS	DESCRIPTION	NUMBER OF MINUTES TESTED	NUMBER OF COPULATIONS
9	77	Normal	6	13
10	88	Normal	30	47
15	82	Normal	30	31
18	64	Normal	30	51
22	76	Anosmic	12	8
23	75	Anosmic	30	30
24	76	Anosmic	30	30
26	82	Blind	30	27
27	82	Blind	20	53
28	88	Semi-vasectomised	30	30
29	84	Semi-vasectomised	20	27

3. *Summary*

By way of summary the points brought out in this account of the prepuberal activity of the young male and the initial copulatory act may be briefly stated as follows:

1. Both males and females devote the greater part of their time to the performance of activities that have no relation to the sexual act.

2. Both males and females smell the ano-vaginal zone. This may be begun as early as the twenty-first day of age. The smelling increases from day to day until the age of thirty-five to forty days is reached, but thereafter the amount remains fairly constant. Toward the end of the pre-mature period the amount of smelling is decreased in the case of some males because of fear of the adults. On the whole the young males smell slightly more than the females.

3. Young males lick their external genitals more than young females. At first the males lick only the sheath, but eventually the licking is directed largely to the glans penis.

4. Copulatory attempts were not made prior to the age when sexual maturity is near at hand (sixty days or over). No play activities of a sexual nature approximating those of the true copulatory act were seen at any time. Observations on approximately fifty young males failed to reveal sexual play such as that referred to by Small ('99) in the case of rats under thirty days of age.

5. Pursuit does not in the early age serve a sexual end.

6. The animals discovered the odoriferous substances placed on the right elbow of the female on the first day it was placed there (twenty-three to twenty-four days of age). They respond to this odor in much the same way as they do to vaginal odors at the outset. Gradually they cease or decrease the amount of smelling of this odor.

7. Sexual excitement does not occur when a receptive female is placed with a young male until the age at which copulatory ability is near at hand (approximately sixty days of age or later).

8. The elementary activities of the copulatory pattern in the young male are generally well coördinated at the time of the first copulatory act. In essential detail the act as a whole resembles that of the experienced male.

9. Somatic sexual maturity as indicated by the presence of free spermatizoa in the reproductive tract does not coincide

exactly with functional sexual maturity as determined by ability to copulate. The normal age at which copulatory ability is demonstrable is probably between seventy and eighty-five days. The variability, however, in animals reared under practically identical environmental conditions is great.

10. The young male is capable of copulating approximately as often during a period of thirty minutes following the initial copulation as an adult rat during a similar period of time. The largest number of copulations following the initial act recorded in this study is 51 in thirty minutes.

STIMULATION LEADING TO COPULATORY RESPONSE

The results of experimental observation indicate that complex congenital behavior is, like the reflexes, conditioned by an hereditary neural organization of receptors and effectors. This hereditary organization differs from that of the reflexes chiefly, if not wholly, in complexity of coördination. Hence it should be possible, because of this close kinship, to subject complex congenital responses to experimental control in a manner similar to that employed in the study of typical reflexes (Sherrington '06), and, by appropriate variation of technique, to analyse and define their adequate activating stimuli and the operation of the receptor-effector mechanism. In this way there would be brought together the kinds of data needed to give a complete account of the operation of complex patterns of congenital behavior in concrete, objective terminology.

The literature on congenital responses contains many statements concerning the rôle of external stimulation in the initiation of patterns of response. A statement from McDougal's "Social Psychology"[3] illustrates the general typc. He says: "In the typical case some sense-impression, or combination of sense-impressions, excites some perfectly definite behavior, some movement or train of movements which is the same in all individuals of the species and on all similar occasions."

---

[3] Sixth Edition, p. 25ff.

In a similar manner Havelock Ellis[3] describes the arousal of sexual activities through particular kinds of exteroceptive stimulation. According to him:

> External stimuli act at every stage, arousing or heightening the process of tumescence, and in normal human beings it may be said that the process is never completed without the aid of such stimuli, either active or in imagination. . . . . The chief stimuli which influence tumescence aud thus direct choice come chiefly—indeed, exclusively—through the four senses of touch, smell, hearing, and sight. All the phenomena of sexual selection, so far as they are based externally, act through these four senses.

He evaluates the four senses with respect to their effectiveness in arousing sexual responses as follows: "Of the four senses—*touch is the more primitive, and it may be said to be the most important,*[4] though it is usually the last to make its appeal felt. Smell, *which occupies the chief place among many animals,*[4] is of comparatively less importance, though of considerable interest, in man; it is only less intimate and final than touch."[5]

Such statements, although lacking in concrete detail, are of interest in this connection because they serve to suggest a feasible point of attack for the study of the activation of the copulatory act. Given an inexperienced male rat which has reached the stage of physiological development denoting copulatory ability, one needs only to supply the adequate stimulus to evoke the copulatory act. Under this condition, a study of the process of activation consists primarily in the analysis and definition of the stimuli acting together with their mediation through the agency of the receptors.

Experiments along these lines, so far as they have been successful, indicate that with further extension of experimentation and refinement of technique the activation of the copulatory response can be described as completely as many of the well known reflexes have been described by the physiologists (Sherrington '06).

---

[3] Psychology of Sex, Vol. 4, p. 1–2 incl.

[4] Italics mine.

[5] Although these quotations are taken from his studies dealing primarily with the sexual life of man, they have in them points of general applicability to the sexual behavior of the lower animals as well, for the fundaments of his sexual theory as a whole are taken from data of comparative physiology and psychology.

1. Experimental control of exteroceptors

From what is known of the functioning of receptors in the activation of well known reflexes (Sherrington '06) it may be inferred, for the purpose of setting up definite working hypotheses that their functions in the initiation of the copulatory act in the rat may be ~~about as~~ follows:

1. They may serve to locate other animals of the same species or animals capable of arousing sexual excitement in the male. As distance receptors they may set up seeking activities.
2. They may serve to differentiate the sexes.
3. They may have a selective sensitivity for certain kinds of stimuli arising from the female in heat. And by means of direct efferent connections with the ganglionic centers concerned with the reproductive mechanism may transmit the necessary impulses to arouse this mechanism to action.
4. They may serve to reinforce nervous processes underlying the sexual response, even though they have no direct reflex connections with the essential reproductive mechanism.
5. Or, by exciting glandular activities, they may cause secretions to be released into the blood stream which have the special function of sensitizing or giving tonus to the neuro-muscular mechanism involved in the act of copulation.

Each of the foregoing possible functions must be tested in the light of available experimental data to determine which if any of them are really involved in the initiation of the sexual act.

A. Vision. Very few references to the visual receptors in the literature on sex-studies indicate clearly the role of visual stimuli either as facilitators or excitors of sexual responses. Examples of the courtship of birds and other animals through display of special adornments or by movements of a particular kind are cited by Morgan ('00, p. 61 ff.) and others. In this case the visual stimuli were thought to be effectual in arousing the pairing impulse in the female bird. Andrews ('14) concludes that visual stimuli are unessential in the conjugation of the crayfish. Banta ('14) states that the wood frog is sexually excited at the mating season by objects moving within the radius of several feet. From this statement we infer that visual stimuli initiated the excitement. No previous investigations of the sexual function of the visual receptors in the rat have come to the author's attention.

a. Operative technique. The eyes of rats were removed under deep anaesthesia. A small piece of sterile cotton was immediately inserted into the orbits to absorb blood accumulating from transected branches of the opthalmic arteries. After all bleeding had ceased and the orbits were cleansed, the eyelids were brought together and overlaid by a small cotton-celloidin dressing. Case reports of the individual animals follow.

b. Experimental results. Rat 26. Eyes removed at age of thirty days. Tested at age of seventy days for copulation. No signs of sexual excitement and no attempts at copulation. Again tested at the age of seventy-seven days. Mounting and palpation of female's sides frequent. Made complete copulatory attempt once but apparently did not effect vaginal entrance. Tested at age of eighty-two days. Copulation appeared for first time. In a period of thirty minutes there were twenty-seven complete acts.

Rat 27. Eyes removed at age of thirty days. Tested for copulation at age of seventy-six days. Showed hyperexcitability but did not attempt to mount. Tested at seventy-seven days of age. No copulation. At eighty-two days the test was again given. Copulation appeared. Record for twenty minutes was forty-nine complete acts. A remarkable exhibition of potency was found in this animal. He copulated thirteen times during the first three minutes, and the same number of times during the second three minutes.

In the foregoing experiments with animals, normal in every way except that visual receptors were not present, no diminution in sexual excitement was observed in the young males prior to the initial copulatory act. Since they responded to the movements of the receptive females by pursuit and mounting, *it is evident that visual stimuli were not necessary for the perception of these characteristic movements.* The age at which copulation began is within the limits of variability for normal males (table 12, p. 127). The number of copulations of each animal during twenty or thirty minutes following the first act gives no indication of handicap either in potency or in ability to find the female in the cage (table 13, p. 128, rats 26 and 27). The copulatory record of no. 27 during twenty minutes exceeds that of any other animal tested in the laboratory. No experimental data is available to indicate to what degree vision is used in locating other animals of the same species or in differentiating animals of the same sex. In the above experiment neither of these functions was called for because of the condition of confinement during the observation. Casual observation of cage activities of rats of various sizes has led to the impression that rats from forty to fifty days of age have acquired habits of responding to the size of other animals without first coming into physical contact with them. If this impression is true, one might expect to find that the blind young males might be much less aggressive in their natural habitat if forced to compete in sexual activities with larger males because of the tendency of the larger to dominate the smaller. The dominating habits of the larger males might bring about an accentuation of the fear and defense response in the presence of other animals of either sex which would effectually shunt all congenital sexual responses.

B. Olfaction. It is generally believed that the sense of smell plays a very important part in the excitation of sexual response in various kinds of animals. This belief is founded upon the observation of males smelling the external genitals of females prior to copulation. In the case of the rat, vaginal smelling is a practice so common that different investigators have considered it an "excitant" to sexual activity. Thus Steinach (10) in discussing the arousal of the sexual impulse in rats assigned to the olfactory sense the function of setting the neural mechanism concerned with the copulatory act into activity after it has been made ready for action by the influence of internal secretions from the reproductive glands. He wrote as follows:

> In bezug auf die Geschlechtsfunktionen kann man genau verfolgen, dasz sich die Wirkungen zunächst auf das Gehirn konzentrieren. Die Ganglien werden instand gesetzt, die vom Weibchen ausgehenden Sinneseindrücke (bie den Ratten sind es namentlich Geruchseindrücke) in Lustgefühle umzuwerten. Es entsteht das, was man heftigen Trieb zum Weibchen oder starke geschlechtliche Aufregung nennt.

In a similar tone von Bechtrew (211, vol. I, p. 395) writes of the rôle of smell: "Im engsten Zusammenhang mit den Geschlects-funktionen steht der Geruchsinn, vor allem in der Tierwelt. Bei vielen Tieren spielt ferner der Geschlecksinn die Rolle eines mächtigen Erregers des Sexualtriebes."

a. Operative technique. A mid-sagittal incision was made in the scalp from points midway between the ears and the eyes. On either side of the incision the skin was retracted thus laying bare the skull. The skull plate was trephined lateral to the mid-line at sufficient distance to avoid rupture of the superior sagittal sinus beneath. With bone forceps a small triangular piece of bone, marked off by the trephine openings, was removed. This opening was just large enough to permit of the insertion of an instrument approximately one and one half millimeters wide. The removal of the small piece of skull plate left exposed the dura mater over the posterior part of the olfactory bulb and the anterior portion of the frontal lobe. Special care in cutting through the meninges was exercised in order to avoid rupture of the superior sagittal sinus. With this small operative field it is usually impossible to sever the olfactory bulb from the frontal pole without rupturing the anterior cerebral arteries as they swing around the frontal poles. The bulb was cut from the brain by introducing a small cautery into the opening of the skull and thrusting it downward to the base of the skull, thence moving it sufficiently both medialward and lateralward to effect complete transection of the bulb just anterior to the frontal lobe. Without removal the cautery was then so manipulated that the tip moved forward in the ethmoidal groove to the posterior wall of the frontal sinus. This served to destroy the filaments of the olfactory nerve which enter the bulb, coming from the nasal end-organs, through the cribiform plate, and provided a safeguard against functioning of olfactory system in the event that a small bundle of fibers of the tract was not transected. Time was allowed for coagulation of the blood coming from the ruptured arteries and veins; then all coagulated blood was removed by means of sterile cotton and the wound was closed. The cut edges of the integument and superficial fascia were brought together and sutured by interrupted stitches and a thin cotton celloidin dressing was applied to the region of the incision.

b. Experimental results. Rat 22. Operated at age of thirty days. Operation incomplete. Second operation age sixty-six days. Successful. Tested at age of seventy-six days. Copulated after eight minutes forty seconds exposure. Record for first twelve minutes was eight copulations. Record of copulations for thirty minutes at the age of eighty-one days was twenty-one. Autopsy showed complete destruction of bulbs.

Rat 23. Operated at age of thirty days. Operation not successful. Operated at age of sixty-one days with complete abolition of smelling. Tested at age of seventy days for eight-minute period. At time for second period female was no longer receptive. No signs of sexual excitement in the first trial. Tested at the age of seventy-five days. Copulated at end of fifty-five seconds after female was placed in cage. Did not effect vaginal entrance. No further attempts in six minutes. In second period of six minutes no further copulations. At third period of exposure, copulation full and complete was renewed at fourteen minutes after female's return to the cage. Record for one half hour was thirty copulations. Autopsy showed complete destruction of bulbs.

Rat 24. Operated at age of thirty days. Incomplete destruction. Second operation at age of sixty-two days. Complete abolition of smelling. Tested at age of seventy-one days for periods of six minutes, eight minutes. No attempts at copulation, although there was frequent mounting without definite clasping and with no palpation. Probably not sexually excited. Tested at age of seventy-six days. No copulation in first period of eight minutes or second of six minutes, but copulation appeared in two seconds after female's entrance in the third period. Record for one half hour was thirty copulations. Autopsy showed complete destruction of bulbs.

Rat 25. Operated at age of thirty days. Operation did not destroy sense of smell. A few days after the operation smelling was renewed. Second operation at age of sixty days. Before the wound had entirely healed a slight scalp infection was noticed which infected the meninges at the point of operation and probably a part of the frontal pole. This caused arrest of growth for approximately two and one-half weeks. Recovery was very slow.

Tested for copulation at age of seventy-six days for periods of eight minutes, six minutes. No mounting or signs of excitement.

Tested at age of eighty-two days for periods of six minutes, five minutes, six minutes, six minutes. Placed fore feet on female's back and bit at her head short time, but was idle after three minutes. No mounting or signs of excitement during first two periods. During third period he jumped on female and clasped her firmly in true copulatory style, but did not palpate or pistonate. Tested at age of eighty-eight days for periods of six minutes, eight minutes, eight minutes. No excitement shown at any of the periods. Idle after first two minutes.

Tested at age of ninety-four days; periods eight minutes, eight minutes, eight minutes. (At this time the testes were small and flacid. The scrotum was pale.) No movements of a sexual nature during the first period. During the second and third repeated mounting and definite clasping without palpation were seen.

Tested at age of ninety-six days; periods eight minutes, eight minutes. During the first period male mounted and clasped several times but did not palpate. Female kicked him with her hind foot and made him wary of her for a short time. During the second period he mounted and palpated and once made the copulatory movements. Entrance to vagina not effected. Mounting repeated several times, but no further copulatory movement. Female non-receptive when third trial was begun.

Tested at one hundred and seven days. Copulated at four minutes, fifty-four seconds after female was placed in cage. Tried to copulate with female at end of fifteen seconds after her entrance to the cage, mounting with her head between his legs. Mounting and palpation frequent before the first copulatory movements were made. Female very resistant, therefore no record for thirty minutes was secured. Autopsy showed complete destruction of bulbs and considerable necrosis in frontal pole.

The foregoing experiments on the removal of the olfactory receptors show clearly that: (1) *The sense of smell is not essential to the appearance of the sexual act in the inexperienced male;* (2) *That is has no direct connections with reflex mechanisms of the copulatory act, the abolition of which will entirely eliminate the act of coition;* (3) *That its excitatory function in the inexperienced male is doubtful, and, if really present under certain circumstances, is not essential to the initiation of the act;* (4) *That in its absence the appearance of the sexual act is neither retarded noticeably nor the potency of the young male modified, providing the operations do not result in complicating factors.*

It seems probable that under normal conditions these receptors are used to some extent in differentiating the sexes, and in certain cases as distance receptors by which the location of the female is determined.

The erroneous nature of Steinach's view is clearly established by the results obtained with anosmic animals in this study. Likewise it has been shown that olfactory stimuli, although possible facilitators of the sexual instincts as von Bechtrew believes, are *unessential* activators and no perceptible modification of behavior follows their elimination. The conclusions with respect to smell are essentially in accord with von Bechtrew's statement as to the importance of the olfactory stimuli for the arousal of the sexual instincts of the dog, except that it lends no support to the view that smell has an excitatory function. With respect to olfactory stimuli and the sexual instinct of the dog, he says:

> Ebensowenig bewirkt die Zweiseitige Abragung der Lobi Olfactori des Hundes eine Störung der Geschlechtsfunktionen. Die so operierten Tiere wiesen analogie Verhältnisse der Libido sexualis auf, wie gesunde Tiere; der einzige Unterschied zwischen ihnen bestand darin, dasz sie, des Geruchssinnes beraubt, nicht selten ihren Geschlechtstrieb nicht nur Während der Laufzeit, sondern auch auszerhalb derselben zu befriedigen suchten.
>
> Man möge hieraus abnehmen, dasz die von einigen Autoren vertretene Ansicht, der Geruchssinn spiele die Hauptrolle der Geschlechtsfunktion, nicht ohne weitererichtig ist.
>
> Dasz der Geruchssinn die Bedeutung eines richtigen Hilfsfaktors für die Erregung des Geschlechtstriebes bei einigen Tieren spielt, ist zutreffend, aber auch nicht mehr, denn auch nach dem Verlust des Geruches befriedigen diese Tiere noch ihnen Geschlechtstrieb. [von Bechtrew ('11) p. 1696.]

C. Vision and olfaction. Since no noticeable effect on the appearance of the act of copulation in the young animal resulting from the loss of sight or smell was found, it was thought advisable to test the effect of removal of the two senses in a single individual before the act had been initiated. The results of this experiment follow:

Rat 30. Operated at the age of thirty days to render anosmic. First operation successful. No attempts at smelling later at any time. Kept in isolation until seventy days of age, then eyes removed and vibrissae cut short. Placed with two others in similar condition for short periods daily, after seventy-third day and until the seventy-seventh day, to accustom him to the contact of other animals in the cage. Tested at age of seventy-eight days for periods of ten minutes and fifteen minutes but no excitement was shown. Copulated at age of eighty-two days after a period of exposure of six minutes. Copulated during the subsequent five minutes as frequently as normal animals. Autopsy showed complete destruction of olfactory bulbs.

Rat 31. Operated at the age of thirty days to render anosmic. Operation successful. Conditions of confinement same as those of Rat 65. Eyes removed at age of sixty-eight days. Tested age of seventy-six days for copulation for periods of twelve minutes and sixteen minutes but no attempts at mounting were made. Tested at age of eighty days. Copulation followed the introduction of the female into the cage in forty-five seconds. Frequency of the act normal. Autopsy showed complete destruction of olfactory bulbs.

Rat 32. Operated at the age of thirty days to render anosmic. Operation successful. Conditions of confinement same as those of the other two above. Eyes and vibrissae removed at age of sixty-eight days. Tested for copulation at age of seventy-six days for periods of twelve minutes and sixteen minutes with no signs of sexual excitement. Tested at age of eighty days. Copulated four and one-half minutes after female was placed into the cage. Autopsy showed complete destruction of olfactory bulbs.

The anosmic rats in which the act of copulation was initiated in the absence of smell only were subjected at a later time to other observations following the removal of their eyes. The results of these tests follow:

Rat 23. (Anosmic and sexually experienced in copulation.) First copulation at age of seventy-five days. Operated at age of eighty-one days to remove eyes. Tested for copulation at age of eighty-eight days, seven days after eyes were removed. *Copulated four seconds after female was placed in cage.* Record for one half hour was thirty-seven copulations.

Rat 24. (Anosmic and sexually experienced in copulation.) On seventy-sixth day of age copulated for period of thirty minutes. Eyes removed at age of eighty-one days. Tested at age of eighty-two days, *one day after eyes removed. Copulated seven seconds after female entered cage.* Record for one half hour was twenty-nine acts.

D. Vision, olfaction and taste. The taste receptors were effectively controlled and eliminated as factors in the initiation of the copulatory response without destruction of the special end organs. The anosmic animals observed ceased all vaginal exploration when brought into the company of the female after the olfactory bulbs were destroyed. Young anosmic animals tested for copulation began the act without any licking of the female either in the vaginal or other regions of the body. Hence it is clear that taste played no part in the arousal of the copulatory response.

E. Vision, olfaction, taste, and vibrissae. Rats 30, 31, 32 when both blind and anosmic were, in addition, without vibrissae. From the age of approximately fifty days the vibrissae were kept cut close to the skin. Both copulated as the records given heretofore indicate without signs of handicap from the loss of vibrissae.

F. Audition. Less is known concerning the function of audition in the initiation of sexual behavior than concerning the other primary senses. Many examples of the use of vocalizations in the courtship of birds are given by Darwin ('01), but in these cases, it appears that the calls were made by the male for the purpose of arousing the pairing impulse in the female. The mating calls of many of the larger mammals during the rutting season are well known, but these calls are means of locating others of their kind, particularly of the other sex. Craig ('14) reports that doves employ vocalizations in the preliminary courting behavior. One male, however, was observed which omitted the calls entirely for a long period of time. Some observations on the sex behavior of the Poitu jacks reported by Pearl ('13) from the Breeder's Gazette indicate that auditory stimuli may become effectual in arousing sexual excitement. Such devices as "sing-song" whistling, and klicking of the latch were successfully employed by the keepers. In this case, the response described is without doubt a result of habit formation. Havelock Ellis (foregoing quotation, p. 44 ff.) is inclined to regard the auditory sense as the least important of the four primary senses for the arousal of sexual desires in man.

In the case of the rat it is probable from observations at hand that under certain conditions (rats blind and anosmic) the male receives auditory cues from the movement of the female about the cage which serve to guide him in his approach to her. Such sounds as the female makes in her cage movements are not of such distinctive character, however, as would permit of differentiating the sexes or discriminating between the receptive and the non-receptive female. Since the female makes no vocalizations characteristic of the oestral cycle it may be assumed, therefore, that these stimuli play no direct part in the arousal of sexual activity in the young male. Experimental results on the control of audition will be given although the data is less conclusive for this sense than for the senses just discussed.

With rats 23 and 24, which were at this time blind, anosmic and without vibrissae, and had previously been observed to copulate, an attempt was made to prevent audition by destruction of the tympanic membrane of the middle ear and filling the tympanic cavity and the external auditory meatus with melted paraffin. Control tests showed that the animals could hear and localize sounds. Next an attempt was made to destroy the cochlear ganglion by the injection of absolute alcohol into the cochlea. Control tests showed that the ability to localize sounds was greatly impaired, but that there still remained some ability to respond to auditory stimuli. Diffusion of the alcohol along the trunk of the auditory nerve affected not only the auditory sense but also the vestibular apparatus with the result that undesirable interference with the equilibratory mechanism was produced. This complication made it necessary to abandon the method and the problem was dropped temporarily until satisfactory technique for the unequivocal control of the auditory receptor could be worked out.

When tested for copulation, both rats 23 and 24 continued to copulate following the partial destruction of the auditory sense organ, although the equilibratory mechanism was greatly disturbed.

G. Cutaneous and deep sensibility. Cutaneous and deep sensibility appear to be the most fundamental senses involved in the arousal of the copulatory response. It is probably the medium through which afferent impulses are aroused which cause the definite mounting clasp, erection of the penis pelvic movements whereby the penis is brought into contact with the walls of the vagina, and the other constituent elements of the copulatory response. Ejaculation, likewise is probably brought about by tactual and thermal stimulation of the penis within the walls of the vagina. Just how these stimuli produce their effects is a problem for future analysis.

Cutaneous and deep sensibility have not been subjected to experimental control in this study. Technical difficulties encountered in the control of their individual receptors are exceedingly great and may prove to be unsurmountable because of their inaccessability and the diffuse distribution throughout the body. The use of drugs for the dissociation of sensibility for particular regions of the body is unsatisfactory because of the difficulty of controlling and limiting the range of drug influence on neighboring tissues. Nerve section followed by gross dissection and histological examination at autopsy to determine the range of distribution of destroyed nerves may be a feasible method of dissociating the cutaneous from the deep sensibility, but this method of approach will involve refinement of technique beyond that now available.

Further definition of the adequate stimulus has been attained through observation of the behavior of young males and adult females at the time of the initial copulation of the former. This has also been accomplished by the use of artificial patterns of stimulation to evoke the sexual act.

2. Artificial reproduction of pattern of stimulation

While young males were being tested to determine the earliest age at which copulatory ability appears it was discovered that the amount of sexual excitement aroused in the young male depended to a marked degree on the excitability and responsiveness of the receptive female. Females that were very sensitive and move quickly upon being touched by the young male were, invariably, most effective in arousing sexual aggression on the part of the male. On the other hand, those that were unresponsive to the light tactual stimuli of the male, sniffing and nosing the ano-vaginal zone, but responded only to vigorous treatment, such as the more aggressive adults were accustomed to administer, seldom aroused strong and prolonged sexual excitement in the inexperienced male. This observation is true for adult males, as well, which are not aggressive or are on the verge of sexual impotency. On several occasions aggressive adult males were seen copulating repeatedly with lethargic females, whereas other potent but less aggressive adults made no attempts whatever.

Practical application of the foregoing discovery was made in an endeavor to provide artificially a movement-stimulus which would serve as an inducement for the young to attempt copulation with a non-receptive rat from which none of the odors characteristic of the female in heat emanated. In this way it seemed probable that some evaluation of the importance of the movement-stimulus could be made in the absence of the olfactory stimulus.

A female, having been tested and found unreceptive, was made extremely sensitive to touch in the vaginal region by painting the root of the tail and the ano-vaginal zone with a very weak solution of hydrochloric acid. She was then placed with a vigorous young male seventy-eight days of age which had not had previous experience in copulation. In a short time the male began nosing and licking in the vaginal region. The female responded to these tactile stimuli applied in the hypersensitive vaginal zone by jumping away from him. Signs of sexual excitement with a tendency to follow appeared at once in the male. This mild excitement and sexual aggression was continued for a few minutes with no accentuation until finally the female upon being touched darted forward suddenly in the cage away from the male. He pursued instantly and, overtaking her with a few bounds, performed the complete copulatory act insofar as this was possible without the coöperative action of the female. He repeated the act again and again before the female was removed from the cage. Similar responses were obtained with another young male by modifying, in a similar manner, the behavior of a non-receptive female so that it resembled the characteristic behavior of the receptive female.

In another instance, a young female guinea-pig, whose size approximated that of an adult rat, was placed into the cage of an inexperienced male seventy-four days of age. This rat had been reared in isolation from the age of thirty-five days. Although he had never before been with an animal other than his kind, he approached the guinea-pig without fear. The latter was moderately tame, but ran from the rat when he touched her while nosing about. In a short time he began smelling and nosing in the vaginal region whereupon the young guinea-pig ran away; but the young male did not pursue at this time. They were left together in the cage for one hour with no signs of sexual excitement on the part of the male. Three hours later, the same guinea-pig was returned to the cage of the rat. As in the previous instance, the latter soon began nibbling and smelling and as before, she darted away when he touched the sensitive regions about the vagina. Gradually after numerous repetitions of the smelling and the female's running away the male began to manifest signs of sexual excitement. Eventually he pursued and attempted to mount her as she darted forward. Mounting attempts more vigorous and persistent followed, and before the period of observation ended he was seen on several occasions in hot pursuit of the guinea-pig with his fore-paws clasping her sides and leaping along behind her on his hind feet as she darted about the cage. Subsequent trials resulted in a repetition of the foregoing behavior. Copulation was not observed.

To summarize the foregoing preliminary experiments it may be said that the following objects are adequate to evoke the copulatory act in an inexperienced male which has reached the proper state of physiological development: an active female in heat, and a female not in heat which has been made to respond to his exploratory activity by quick movements resembling those of a female in heat. Sexual excitement was aroused followed by partial attempts at copulation by a small guinea-pig which moves about the cage in a manner somewhat resembling that of the female in heat.

GENERAL REMARKS

The scope of this study is limited to an account of the copulatory pattern and its activation. Data bearing on the internal factors which condition the response will be presented in a subsequent paper. In its present stage of completion this investigation leaves many unsolved problems for future consideration, but, nevertheless, it demonstrates clearly the fruitfulness of the experimental method of approach. Certain data considered briefly in the foregoing pages are of sufficient importance because of their bearing on the general subject of congenital behavior to justify greater emphasis than heretofore given.

1. Three fundamental aspects of congenital behavior

From the standpoint of objective psychology, the chief lines of interest in unmodified congenital behavior center in three fundamental aspects of its nature and operation. These lines of interest call for studies of particular patterns of congenital behavior for the purpose of analyzing: (1) The constituent elements and their temporal, serial, and functional relationships; (2) The kinds of stimuli adequate to evoke the unit of response under observation and the manner in which they activate the effectors through the medium of the receptors and the nervous system; and (3) The internal factors operating within the organism to (*a*) provide the special structures, if any, involved in the response, (*b*) to integrate these and other structures into mechanisms for coördinated action, and (*c*) to sensitize the receptor-effector mechanism for response of a definite pattern to stimuli of a special character.

Having analyzed each of these aspects, the experimenter will then be prepared to give not only a detailed account of the initial appearance of the pattern of behavior studied, but also will have acquired the factual background needed to facilitate an examination of the modification it undergoes during a life of exercise in an ever changing environment. Thus can be brought together a valuable fund of scientific information which will be of service to students of psychology and closely related sciences who are concerned with the application of all available facts in the field of native behavior.

2. The copulatory act an hereditary mechanism

The results of this investigation substantiate the generally accepted view that the copulatory response is the action of an hereditary mechanism. No evidence was found supporting the view expressed in a recent paper (Kuo '21), in which, if my interpretation of the article is correct, the author denies the hereditary organization of such mechanisms. He regards them as products of experience. A careful consideration of the experimental data on this subject indicates quite clearly, it seems, that this latter view is not in harmony with the existing facts.

3. Precision in the initial copulatory act

The copulatory act differs quite strikingly from many of the early post-natal responses with respect to the precision of functioning of its elementary components. Greater precision is to be expected, however, because of the more advanced stage of physiological development reached by the animal prior to the first copulatory act. The slight irregularities described in a foregoing section of the paper may be variously explained. In some instances they are probably the result of physiological immaturity of some of the structures involved; in others, due to incomplete integration of the elementary activities of the copulatory unit or to incomplete dissolution of these elements from other distinctly foreign units with which they have functioned previously; or, again, they may arise from the failure of neural arcs of the copulatory act to gain priority over other arcs aroused by stimuli acting simultaneously with the stimulus adequate to evoke the copulatory act.[6] The vigor of the copulatory mechanism in the young male, as measured by the number of complete copulatory attempts made in a given time interval, closely approximates that of the experienced adult. This, however, cannot be taken as a measure of relative precision in the delivery of the spermatazoa and their fluid media to their proper receptacle in the reproductive tract of the female. Data which indicate the rate and range of improvement in this function are not available.

4. Native and modified native elements comprise the copulatory act

Inspection of the constituent activities of the copulatory pattern reveals a point[7] that has oftimes been described in the literature on delayed responses. The act is a compound of both native and modified native or acquired responses. The latter have been exercised in connection with other units of response and habitual performances from the time of their initial appearance to the time of their incorporation in the copulatory pattern. It is important to note, however that these elementary acts exercised in prepuberal life were not substitutes for or abbreviated and playful types of the copulatory act. The evidence does not show that their early exercise was, in some mysterious manner, pointed toward acts of greater precision in the reproductive function. Such activities as pursuit of other rats, playful clasping, wrestling, vaginal smelling, and nibbling have no demonstrable connection with the copulatory act prior to their incorporation in this act at or near the age of physiological sexual maturity. The function of penis licking is still a matter of conjecture. Though it may sometimes be shown to be a form of masturbation or in other respects connected with the process of tumescence or detumescence, there is no evidence at the present time which links it with the activation of the copulatory act. Palpation of the female's sides, piston movements of the pelvis, and the backward lunge characteristic of the copulatory act are activities which have never been observed prior to the first real copulatory attempts.

---

[6] Sherrington, C. S., The Integrative Action of the Nervous System, p. 231.

[7] See especially Morgan, C. Lloyd: Animal Behavior, 1901.

The evidence from this study harmonises, on the whole, with the view that the elements of the copulatory act are integrated into a functional unit of response at a rather definite period of the rat's life. Prior to this integration they do not function in isolation or in smaller units of action which are the anlage of the copulatory act. This point is of special interest because of its bearing on the sexual theories of infancy promulgated chiefly by the Freudian School. Because of the relation such facts have to this interesting subject, it is desirable to extend the present osbservations to other animals and to the human infant as well to determine to what degree these findings are common. In this way data will be made accessable to test the correctness and appraise the value of these theories.

5. *The adequate activating stimuli*

Analysis of the activation of the copulatory act is not sufficiently advanced, as yet, to enable one to define accurately the stimuli adequate to evoke the copulatory response on the first occasion of its appearance. It may be said, however, on the basis of available data, that the adequate stimuli are probably both mechanical and thermal in nature, and that they are almost certainly mediated through the cutaneous receptors and the receptors of deep sensibility. In some way the movements of the female ordinarily supply the stimuli which under the proper conditions initiate the act. The effectiveness of these stimuli is assured, as will be shown later, only after certain internal factors have done their work toward preparing the receptor effector mechanism for response to this particular pattern of stimulation.

6. *Fundamental need of more experimental data on congenital behavior*

Heretofore no special comment as to the bearing this study has on the current discussions of "instinct" has been given. The use of this term is unnecessary in the exposition of experimental data; furthermore, its use is undesirable in this connection because of the difficulty in so defining the term as to disentangle it from its many obsolete and unscientific attachments.

It must be obvious to all who have reviewed recent discussions of the term "instinct" that the chief cause of our inability to elucidate the field of congenital activity cannot be attributed primarily, or even in large measure, to the general *abuse* of the term, "instinct," or any of its equivalents. Neither is it due primarily to faulty interpretations of the past or deprivation of plausible interpretations just recently brought forward. The cause is far more fundamental. The difficulties cannot be obviated by discussion alone. They must be overcome through experimentation. The paramount need at the present time is a broader factual acquaintance with the detailed nature and operation of congenital behavior mechanisms. It is a need which must be met by carefully planned and executed studies of native behavior designed to give facts making possible a complete account of patterns of congenital behavior, their activation, their internal conditioning factors, and finally their modifications through exercise. Results of this kind should be a reliable guide in determining what classificatory terms must be discarded, re-defined, shorn of their unscientific encumberances, or enriched by further interpretation.

CONCLUSIONS

The data herein presented seem to justify the following conclusions:

1. On the whole the evidence brought forward indicates that the chief elements of the primary reproductive act appear within a short period of time at the age of puberty. Activities such as smelling the vagina, pursuit and playful clasping seen in wrestling have no definite connection with the copulatory act prior to the age of sexual maturity. At that time the function of smell in the initiation of the act is wholly negligible. Licking the penis appears in prepubertal life at about the forty-fifth day and probably serves the same function thereafter when acting in isolation as when it is incorporated in the copulatory pattern. Palpation of the female's sides, pelvic movements, and the backward lunge are elements of the act which have no exercise in prepubertal life.

2. The *overt* pattern of the sexual act consists of the following elements: (*a*) Pursuit and mountings; (*b*) palpation of female's sides. (*c*) depression of lumber region of back, on the part of the female, with the consequent elevation of the sacro-coccygeal region; (*d*) pelvic movements of the male by which the penis is thrust in piston-like action toward the vagina; (*e*) cessation of palpation of female's sides and the backward lunge; (*f*) licking the penis.

3. Differences between the initial copulatory act and the act as modified by age and experience are found. Minor differences, due to purely physical limitations of size and strength, are found in the location of the fore-paws on the female's sides, vigor of

palpation of female's sides, and reduction of force of backward lunge. More important differences are: Increase of aggressiveness with sexual experience; incomplete patterns of the act involving omission of the essential elements such as palpation, pelvic movements and backward lunge; failure to lick the penis after copulation; and mounting in a manner that will not permit the completion of the full copulatory act, i.e., mounting at head.

4. The age at which the initial copulatory act appears is related to general physical development. The earliest age at which the act was initiated in this study was sixty-four days. It does not appear prior to somatic maturity. On the other hand, somatic maturity is not a reliable indication of copulatory ability.

5. The number of copulations following the initial experience compares favorably with that of adult males. The usual number during thirty minutes subsequent to the first act is from twenty-five to thirty-five. The greatest number observed in this study was 53 during the first twenty minutes.

6. The movements of a receptive female appear to supply the adequate stimuli for the initiation of the copulatory act. Movements of adult rats that simulated those of a female in heat brought out sexual acts, complete in pattern from the male's standpoint, in the case of two males that had not had sexual experience. The quick movements of a guinea pig served to arouse great sexual excitement in a young male. Excitement was accompanied by mounting attempts, but no complete acts.

7. Sensory controls reveal the following:

a. Visual stimuli are not essential to the initiation of the copulatory act. No visible effects in their absence are seen in the nature of the pattern, the pursuit tendency in mounting, the age of first copulation, or the rate at which copulations may take place.

b. Olfactory stimuli are not necessary for the arousal of sexual excitement or the initiation of the copulatory act. Their absence neither retards the age at which the act first appears, or modifies the sexual drive as manifested by eagerness to copulate and ability to copulate for a prolonged period of time.

c. Elimination of visual, olfactory, gustatory sense organs and the vibrissae prior to sexual experience produces no changes in the sexual act, either in the pattern, the age at which it appears, or the responsiveness to stimulation of a female in heat. Substitute action of the visual, olfactory, or gustatory senses is, therefore, improbable.

d. Partial elimination of auditory sensitivity in blind and anosmic rats after sexual experience makes no change in the ease or arousing the pairing impulse. Experiments of this evidence that audition is an essential receptor for the initiation of the copulatory act in the rat.

e. The lack of evidence for any important function of each of the other primary senses in the initiation of the copulatory act points to cutaneous and receptors of deep sensibility as the primary organs that mediates the exteroceptive stimuli by which the act is initiated.

REFERENCES

Andrews, E. A.: Conjugation in the crayfish. Jour. Exp. Zool., 1914, 9, 235–265.

Banta, Arthur M.: Sex recognition and the mating of the wood frog. Biol. Bull., 1914, 26, 171–184.

von Bechtrew, W.: Die Funktionen der Nervencentra. 1908, 3, 1.

Craig, Wallace: Behavior of young birds breaking out of the egg. Jour. of Animal Behav., 1913, 2, 296.

Craig, Wallace: Male doves reared in isolation. Jour. of Animal Behav., 1914, 4, 121–133.

Darwin, Charles: Descent of Man. Popular Edition. London, 1901.

Ellis, Havelock: Studies in the Psychology of Sex, 3, 4.

Groos, Karl: The Play of Animals. 1898.

Hamilton, G. V.: A study of sexual tendencies in monkeys and baboons. Jour. of Animal Behav., 1914, 4, 295–318.

Hewer, Evelyn E.: The effect of thymus feeding on the activity of the reproductive organs in the rat. Jour. of Physiol., 47, 479–490.

Kirkham, Wm. B.: The breeding habits, maturation of eggs and ovulation of the albino rat. Amer. Jour. of Anat., 1913, 15, 291–317.

Kuo, Zing Yang: Giving up instincts in psychology. Jour. of Philosophy, 1921, 18, no. 24, 645.

McDougal, Wm.: An Introduction to Social Psychology. Sixth Ed. 1912.

Miller, Newton: Reproduction in the brown rat. Amer. Natural., 1911, 45, 623–635.

Montane, Louis: A Cuban Chimpanzee. Jour. of Animal Behav., 1916, 6, 330–333.

Sherrington, C. S.: The Integrative Action of the Nervous System, 1906.

SMALL, W. S.: Notes on the psychic development of the white rat. Amer. Jour. of Psychol., 1899, 2.

STEINACH, E.: Untersuchungen zur Vergleichenden Physiologie der Männlichen Geschlechtsorgans. Pflüger's Archiv., 1894, 56.

STEINACH, E.: Geschlectstrieb und echt sekundäre Geschlechtsmerkmale als Folge der inneresekretorischen Funktion der Keimdrüsen. Zentralbl. f. Physiolog., 1910, Bd. 24.

STEINACH, E.: Willkürliche Umandlung von Säugetiermännchen in Tiere mit ausgeprägt weiblichen Geschlechtscharakteren der Keim drüsen. Archiv. f. d. ges. Physiol., 1912, Bd. 144.

STEINACH, E.: Feminierung von Männehen und Maskulierung von Weibchen. Zentralbl. f. Physiol., 1913, 27, 717–723.

FATIGUE EFFECTS AS MEASURED BY SUGAR CONTENT OF BLOOD[1]

BUFORD J. JOHNSON

From the Bureau of Educational Experiments, New York City

The purpose of this investigation was the study of changes in the sugar content of the blood of children as related to different kinds and amounts of activity. Observations of children in the performance of varied activities indicate the need of other criteria of fatigue than diminished capacity or decrease in output in a given activity within a given period of time. In some cases the stimulating factors in the situation lead to a continued output that is relatively good, though the effort expended would indicate the presence of fatigue. In other cases the decrease in output is greater but the assumption that there is greater fatigue present does not seem justified. The intensity of the stimulus to activity is doubtless conditioning the output and interfering with such a form of fatigue test. The tendency to combat the onset of fatigue by exaggerated activity is often noted. This leads to speeding up or spurts and also to a slowing up and increased tension or force in movements. With repetition of the activities at short intervals the behavior of individuals tends to fall into types which emphasize the preceding assumptions.

There is lack of uniformity among investigators concerning the change in sugar content of the blood under continuous working conditions. That a slight but steady increase may occur in the rate at which adrenalin enters the circulation during exercise is held by some writers. Schneider and Havens (1) report an increase in the output of adrenalin with the onset of muscular activity. Cannon (2) holds that adrenalin is secreted under the stimulatory effects of anticipation, enters the blood stream, and increases the functional capacity of muscles. He reports glycosuria after muscular exercise and also after scholarship examinations as evidence of increased sugar content of blood. Stewart and Rogoff (3) found that external manifestations of emotional excitement and presumably, therefore, the visceral concomitants of emotion could be evoked in a perfectly normal manner in animals whose suprarenal glands have been isolated from the central nervous system. Bainbridge (4) reviews the experimental evidence and concludes that the share taken by adrenalin in bringing about the circulatory and other changes taking place during exercise, even when this is carried out under emotional stress, is comparatively small. In a study of the blood of dogs during exercise, Scott and Hastings (5) found that the concentration of sugar falls steadily throughout the work period. Brōsamlen and Sterkel (6) assert that the contradictory statements concerning the change in sugar content of the blood that occurs after muscular exercise are due to variations in interval between end of work and determination of blood sugar value. They made determinations before and after exercise, then followed this latter determination by four others made at intervals varying from forty minutes to one hour and twenty minutes. The following data for healthy adults from their study show the irregularity as to decrease or increase in sugar content immediately after exercise.

---

[1] A briefer report of this investigation was made at the meeting of the American Psychological Association in Princeton, December, 1921.

INDIVIDUAL	AGE	TIME OF FIRST DETERMINATION	FIRST SUGAR CONTENT	TIME WORK ENDED	TIME OF SECOND DETERMINATION	SECOND SUGAR CONTENT	VARIATION
		a.m.		a.m.	a.m.		
A.	24	7:00	0.086	7:40	7:50	0.082	−4
B.	26	7:20	0.093	8:05	8:20	0.085	−8
C.	33	7:05	0.088	7:50	8:20	0.102	+14
D.	27	7:10	0.078	7:50	8:20	0.074	−4
E.	32	6:20	0.096	6:50	7:00	0.104	+8
F.	22	6:20	0.094	7:00	7:10	0.082	−12
G.	18	7:20	0.076	8:05	8:20	0.087	+11
H.	40	7:10	0.082	8:05	8:20	0.082	0
I.	28	7:10	0.092	7:55	8:05	0.087	−5
J.	21	7:00	0.082	7:50	8:05	0.084	+2

They conclude that normally the blood sugar varies little when the body is at rest and fasting, but that fatiguing work by healthy adults generally causes a slight decrease in the sugar content of the blood. The values fluctuate and the lowest value is found at varying intervals after the end of the work. The difference between the rest value and this lowest value amounts on the average to 0.020. There is then a gradual increase in blood sugar, the maximum increase occurring from one and one half to four hours after the end of the work.

We realize that our data are not conclusive either as to the expected change in sugar content of blood for children after certain kinds of activities or as to the use of blood sugar determinations as a criterion of fatigue. The value of such a method can only be determined by more intensive studies. So few data are available of repeated tests on children under specified conditions that we believe our records are important as a basis for further investigations.

PROCEDURE

In December, 1920, eleven subjects were selected as being susceptible to fatigue effects to a greater extent than other children under observation. The selection was made jointly with Dr. Edith Lincoln, whose physical examinations of these children indicated relatively low resistance to fatigue. Our selection was based upon decrease in output as measured by psycho-physical tests in the laboratory and also upon apparent effort expended to make the scores. Only eight subjects, four boys and four girls, were available for the complete experiment with the determinations of sugar content in the blood.

Two series of laboratory tests were devised, one of relatively simple muscular tests, the other involving more complex mental reactions. An attempt was made to establish a standard or reference measure of blood sugar content for each individual for the time of day at which the tests were to be given. Two blood sugar determinations were made with a three weeks interval. These determinations were made by Dr. Liggett Lincoln. In making a determination the procedure was to bring the child up to the laboratory for obtaining a specimen of blood, after which he went back to the school room without any work in the psychological laboratory on those days. This was also held to be desirable for adapting the child to such conditions so that we might prevent undue emotional excitation on the days of the test series. These children are familiar with the laboratory and with the examiners; both physician and psychologist have made studies of these children throughout a period of two to three years in each case. Although two children hesitated about the blood test, such experiences as the punctures for blood specimens have not lessened the interest of the children in coming to the laboratory, opportunities for which they solicit. This desire was the strongest incentive during the experiment for one boy who has evinced fear of even slight physical pain. Three weeks elapsed between the time of the second preliminary blood test and the first experimental series. The experiments were made at the same time of day, between 9:30 and 12 in the morning, keeping the order of individuals the same as far as was possible. Breakfast was not omitted. Diet lists showing the food eaten at breakfast had been obtained. The physician considered the breakfasts for all the children fairly standardized as to amount and type of food. More than two hours elapsed between breakfast and test in each case.

A preliminary study was made of the test used in order to determine a series of simple muscular tests in which practice effects could be practically eliminated, and to acquaint the child with the procedure so that he would be at a high level of activity between blood tests. In the spring preceding this study, the target, coördination, tapping, and dynamometer tests were given to a group of children including those to be used in the fatigue experiments. Trials were given daily for nine school days, Saturday and Sunday intervening between the fifth and sixth trials. The curves in figures 1 and 2 show an approximate elimination of practice effects in tapping and coördination. The target records for 30 throws a day continued to show marked fluctuations with little trend toward increased skill in many cases. It was a favorite performance; and the throwing of 100 darts in the fatigue experiment offered an activity adequate to the production of muscular fatigue activity which mere scores do not measure.

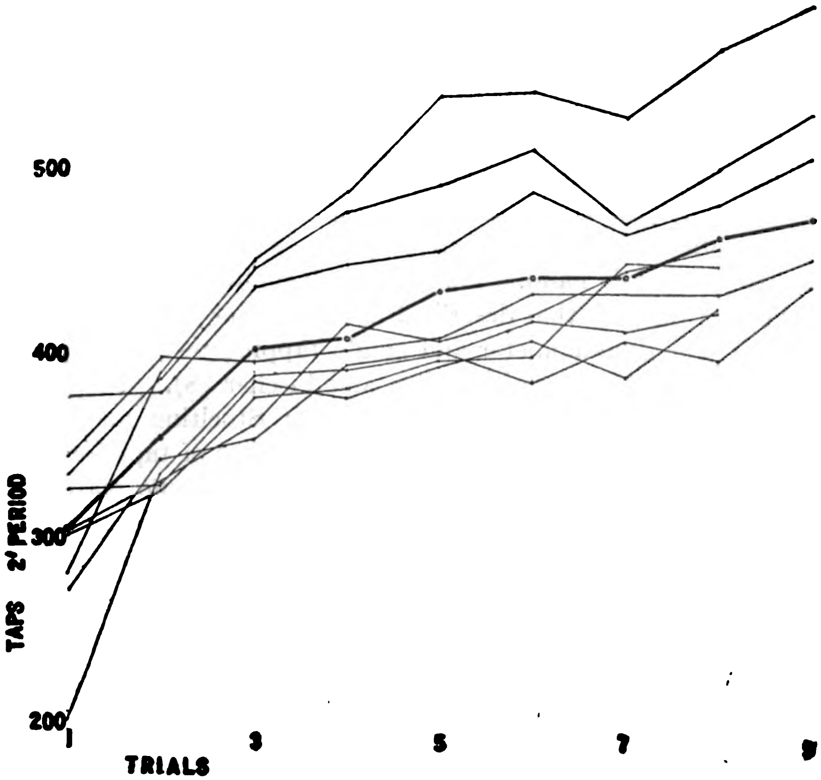


FIG. 1. SHOWING THE PRACTICE EFFECTS IN THE TAPPING TEST, ALTERNATE PLATE

The light lines are individual curves; the heavy line is a group curve representing the daily average scores.

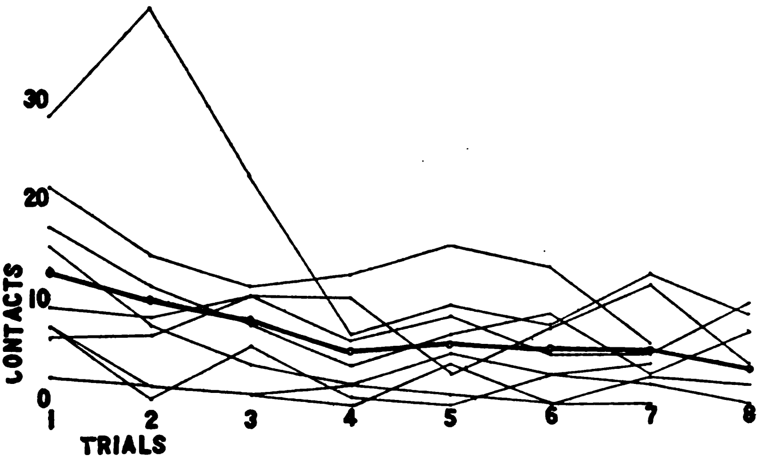


FIG. 2. SHOWING THE PRACTICE EFFECTS IN THE COÖRDINATION TEST

The light lines represent individual scores; the heavy line, average scores for the group.

Series I. Simple muscular tests

This series included: Target, 100 throws with right hand; dynamometer, 10 trials, left hand; tapping, alternate plate, for two minutes with right hand; tapping, single plate, for two minutes with left hand. They were given in the order listed. The target test was that described by the writer (7) in a former article. The dynamometer and single tapping tests were given according to directions of Woolley and Fischer (8). The alternate tapping plate (9) was so wired that Stoelting make and break counters recorded separately the number of taps for each plate. The child was instructed to strike first one plate and then the other. A few taps were not recorded because the dividing block was struck instead of the plate and also failure to touch the plate was noted even when movement was made approximating contact.

Immediately before the child came into the room for the testing a specimen of blood was obtained by the physician in an adjoining room. The testing required from twenty to twenty-five minutes, varying slightly for individuals because of time variations possible in two tests, the dynamometer and target. Another specimen of blood was obtained immediately after the testing.

In table 1 the sugar content for the preliminary blood tests is shown. We have not been able to get definite standards as to normal sugar content of blood for the ages considered.[3] Some of these children vary between the first and second tests as much as 11 mgm. per 100 cc. while others show as little variation as 1 mgm. per 100 cc. The average sugar content for the group for the first blood test was 113.57; for the second test, 117; for the third test, 120.125. Of the six individuals considered, two cases show a decrease with variations relatively large. The range of individual variations is from 0 to 26. Only one case shows a decrease in sugar content from the preceding blood test, but this is the largest variation found. Another case shows an increase of 25. These two individuals seem especially susceptible to fatigue and are also easily stimulated to emotional responses. These percentages of blood sugar are high as com-

---

[3] Norms vary for different observers. Summaries of these normal values are given by A. Mertz, Archiv. fur Kinderheilkunde, 1920, lxviii, 260. From 2 to 5 years, blood sugar values range from 0.084 to 0.100; from 2 to 8 years, 0.080 to 0.120; from 2 to 14 years, 0.072 to 0.113; from 6 to 14 years, 0.072 to 0.108. Mertz, A. and Romiger, E., Archiv. fur Kinderheilkunde, 1921, lxix, 105, give additional data for ages from 7 days to 1 year, 7 days, for which the blood sugar values range from 0.068 to 0.101 with average of 0.081.

TABLE 1

Preliminary blood sugar tests

	AGE AT FIRST BLOOD TEST	HEIGHT-WEIGHT INDEX	BLOOD SUGAR (MGM. PER 100 CC.)	
			December 18, 1920	January 8, 1921
	years			
G. P., girl	6.04	0.95	0.090	0.100
J. S., boy	7.22	0.92	0.139	0.128
D. P., girl	7.70	1.03	0.105	
T. F., boy	8.29	1.18		0.120
E. C., boy	8.86	1.08	0.128	0.120
E. R., girl	8.87	1.07	0.112	0.116
J. M., boy	9.14	1.18	0.110	0.115
M. D., girl	11.01	1.23	0.111	0.120
Average			113.57	117

TABLE 2

Series I. Simple muscular exercise

	TARGET SCORE	DYNAMOMETER AVERAGE SCORE	TAPPING (2 MINUTE PERIOD)		BLOOD SUGAR (MGM. PER 100 CC.)	
			Single plate	Alternate plate	Before exercise	After exercise
G. P.	65	9.3	526	344	0.120	0.126
J. S.	246	8.2	429	268	0.130	0.125
D. P.	82	11.0	517	424	0.102	0.110
T. F.	222	14.1	286	258	0.126	0.152
E. C.	117	11.6	591	446	0.120	0.124
E. R.	140	7.7	429	361	0.090	0.120
J. M.	342	12.6	510	423	0.128	0.130
M. D.	169	12.3	411	510	0.145	0.142
Average					120.125	128.63

pared with values usually given for children and adults. They exceed any blood sugar given by Brösamlen and Sterkel (10) for healthy adults. When we average the three blood sugars preceding series I for each individual and get the group average we have 117.89 with standard deviation of 8.44. The group average after the tests was 128.63 with a standard deviation of 12.142. The difference between this and the average of the blood sugar determinations preceding the testing is 8.5 which equals 1.78 times the probable error. Correlation of the blood sugar ratings immediately before series I with those immediately after gives r = 0.53. There is evident a slight increase in blood sugars after the simple muscular exercise.

TABLE 3

Repetition of muscular tests, April 19, 1921

	DYNAMOMETER AVERAGES FOR RIGHT HAND			ADDING MACHINE	TAPPING—SEPARATE PLATES						BLOOD SUGAR (MGM. PER 100 CC.)	
					Right hand			Left hand				
	First 5 trials	Second 5 trials	Third 5 trials		(1)	(2)	(3)	(1)	(2)	(3)	Before exercise	After exercise
T. F.	22.2	19.2	20.7		472	450	522	445	521	441	115	120
E. R.	13.2	13.4	12.8	56	*	477	378	*	354	275	112	125
M. D.	19.4	22.0	18.0	66	494	435	436	436	422	369	116	118

* Wire was loose and record lost for first trials.

Two of these children showed such a large amount of sugar and one showed so great an increase in sugar content that a repetition of muscular tests was made. Blood sugar specimens were again obtained immediately preceding and following the tests. The tests given were tapping, dynamometer and exercise upon an adding machine. The tapping was done with both hands on separate plates with the board so wired that records were separately kept for each hand. Three trials were given with thirty second intervals. With the dynamometer fifteen trials were made with the right hand. The adding machine was arranged so that 1 was printed each time the handle was pushed back. The child was instructed to do this as rapidly as possible. It was continued for one minute. The sum printed was recorded as the score.

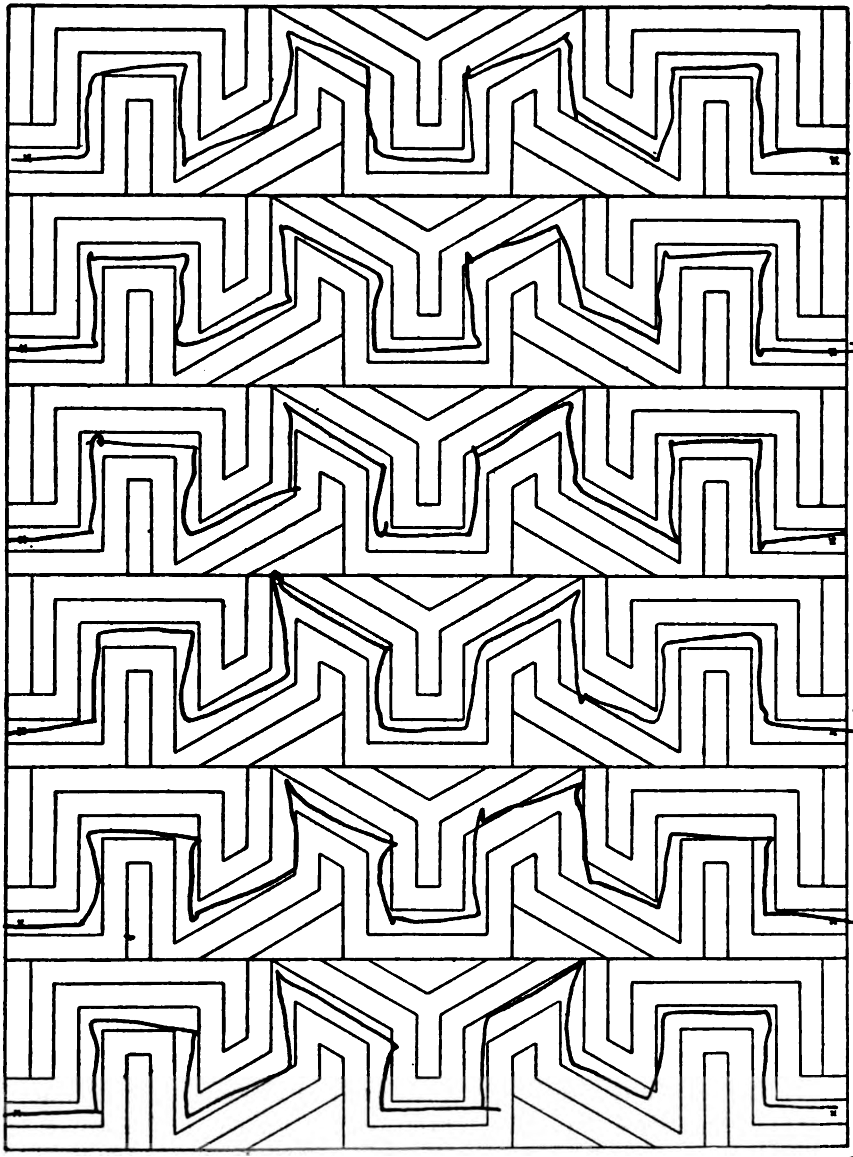
The sugar content for two of these cases was not nearly so high before these activities as in the first series and there is but a slight change after exercise. The third case has a sugar content higher by 22 than that preceding the first muscular tests but does not show so great an increase after exercise. though the blood sugar then is the highest for this child during the experiment. A slight increase in blood sugar after exercise is found for all three subjects.

Series II

The second series for producing fatigue from more complex reactions involving little muscular exercise was given May 17, 1921. The same procedure was followed in obtaining blood specimens both before and after the activities in the laboratory. The tests were given in the following order: coördination, discrimination, memory for digits, and substitution. In the coördination test (fig. 3) the child was instructed to trace a path without touching the sides, but in tracing a given segment to make a stroke of the pencil to the beat of the metronome. This was set at one hundred beats per minute. An actual record made during the experiment is shown in figure 3. Number of contacts and time were recorded.

The discrimination test involved the sorting of fifty-two ordinary playing cards. In the center of each card was cut a diamond-shaped hole. The holes were so cut that in thirteen cards the long axis of the diamond was lengthwise the card; in thirteen cards it was crosswise the card; in thirteen cards it extended in the diagonal from the upper right to the lower left; in the remaining cards from the upper left to the lower right. A wooden receptacle of five open stalls was clamped to a table under an adjustable screen so that the stalls and cards could not be seen. The cards, carefully shuffled, were placed in the end stall at the left. The subject was instructed to take from the top of the pack one card at a time with the left hand and while holding it in this hand to run the thumb and forefinger of the other hand around

M. D. 5/17/21 1 min 4 sec.



4

3

3

3

7

6

26

Fig. 3. An Actual Record in the Coördination Test

the edge of the hole. He was then to place the card in that stall designated for cards with the diamond in that position. The sorting continued in this manner until all the cards had been distributed. The record sheet in figure 4 shows the type of errors made.

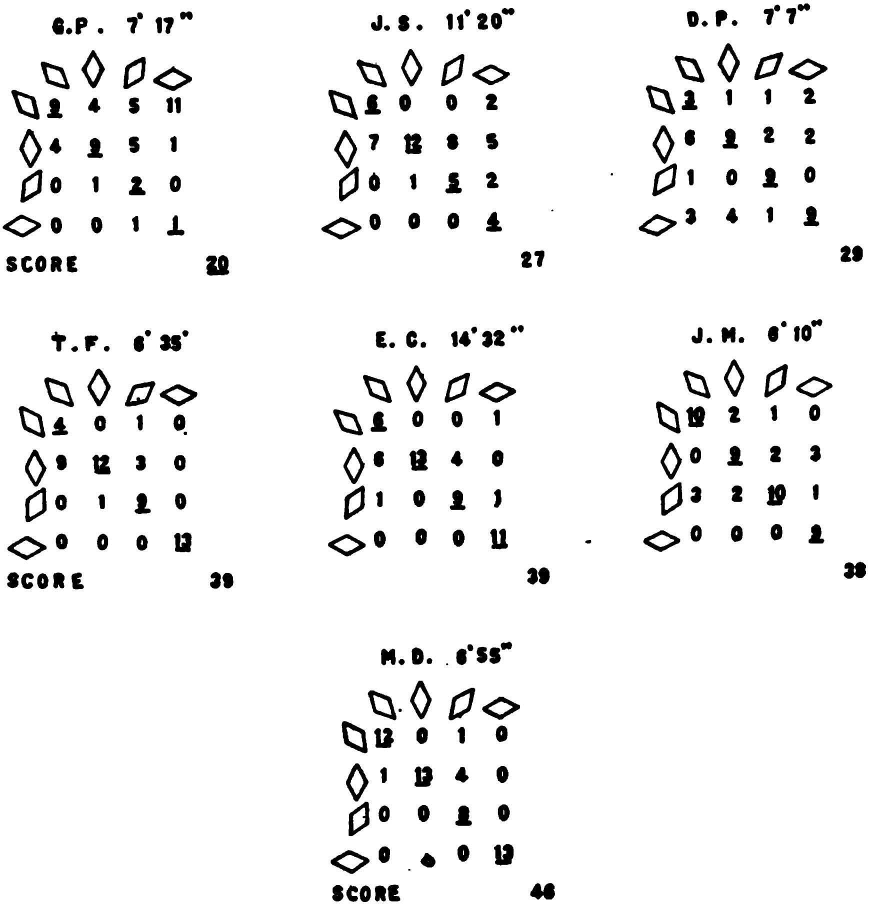


FIG. 4. RECORD OF TIME AND PLACEMENTS IN THE DISCRIMINATION TEST

In the test of memory for digits the procedure followed was that described in the monograph by Woolley and Fischer (11) previously mentioned. The substitution blank used was a symbol form devised by Dunlap. A record made by the youngest

G P 5/17/21 4 min 16 sec Correct

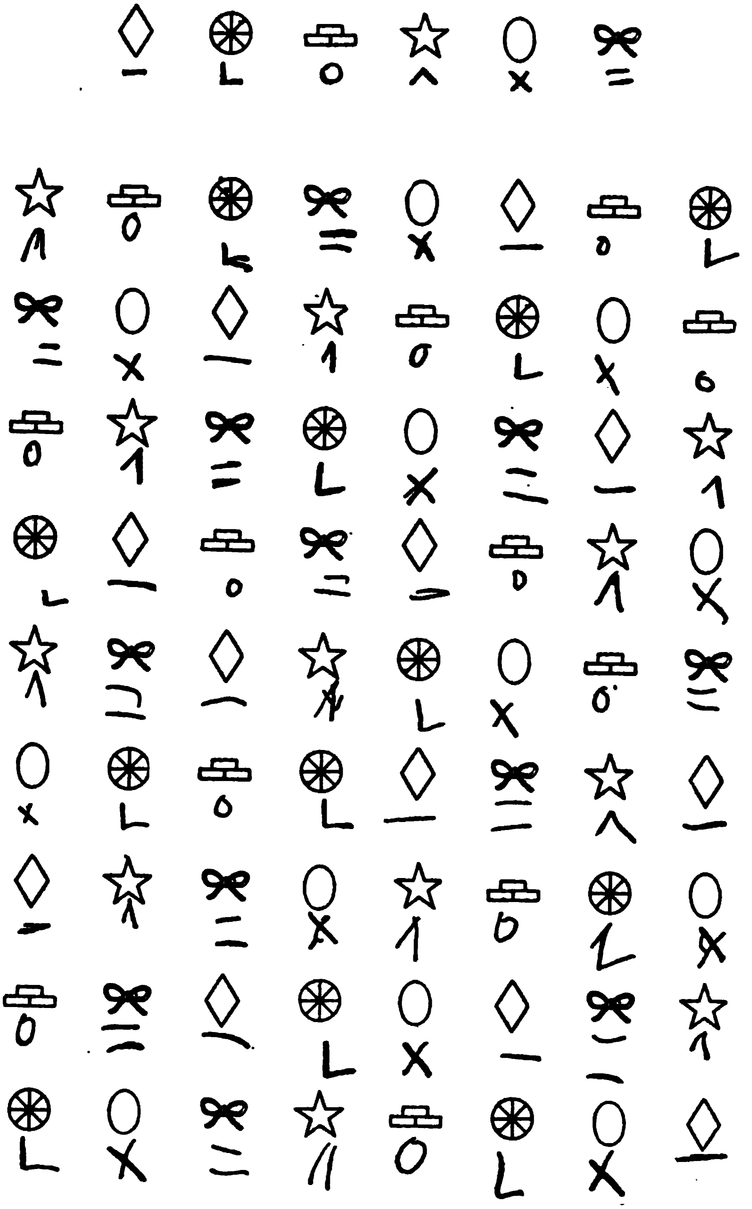


FIG. 5. RECORD MADE BY THE YOUNGEST CHILD IN THE SUBSTITUTION TEST

child is shown in figure 5. It was required that symbols be substituted for symbols.

TABLE 4

Series II, May 17, 1921

	MOTOR COORDINATION TEST		FORM DISCRIMINATION		MEMORY FOR DIGITS		SUBSTITUTION (FORM 1)	
	Time	Number of contacts	Time	Score	Span	Score	Time	Errors
G. P.	1′ 26″	38	7′ 17″	20	5	40	4′ 16″	0
J. S.	1′ 11″	36	11′ 20″	27	6	66	4′ 10″	0
D. P.	1′ 30″	20	7′ 7″	29	7	100	3′ 4″	1
T. F.	1′ 29″	42	8′ 35″	38	4	31	2′ 43″	0
E. C.	1′ 10″	38	14′ 32″	39	9	175	3′ 18″	0
J. M.	1′ 20″	14	6′ 10″	38	9	164	3′ 4″	2
M. D.	1′ 4″	26	6′ 55″	46	7	101	2′ 28″	0

TABLE 5

Series II. Blood sugar, blood pressure and urinalysis, May 17, 1921

	BLOOD SUGAR (MGM. PER 100 CC.)		BLOOD PRESSURE		URINALYSIS AFTER EXERCISE FOR SUGAR	PREVIOUS BLOOD PRESSURES		
	Before exercise	After exercise	Before exercise	After exercise		1918–19	1919–20	1920–21
G. P.	85	89	$\frac{88}{60}$	$\frac{102}{62}$	None	$\frac{78}{58}$ $\frac{78}{56}$	$\frac{92}{62}$	$\frac{90}{70}$
J. S.	90	88	$\frac{108}{74}$	$\frac{90}{68}$	None		$\frac{90}{58}$	$\frac{94}{72}$
D. P.	81	84	$\frac{96}{72}$	$\frac{96}{68}$	None	$\frac{90}{58}$ $\frac{92}{60}$	$\frac{88}{62}$ $\frac{90}{56}$	$\frac{92}{68}$
T. F.	88	90	$\frac{102}{72}$	$\frac{98}{76}$	None	$\frac{106}{66}$ $\frac{110}{66}$	$\frac{96}{58}$	$\frac{104}{76}$
E. C.	92	85	$\frac{110}{76}$	$\frac{110}{72}$	None			$\frac{98}{76}$
J. M.	100	102	$\frac{96}{64}$	$\frac{100}{66}$	None	$\frac{78}{66}$ $\frac{82}{66}$	$\frac{90}{64}$ $\frac{90}{64}$	$\frac{98}{76}$
M. D.	101	110	$\frac{122}{78}$	$\frac{98}{78}$	None	$\frac{88}{64}$ $\frac{86}{64}$	$\frac{88}{62}$	$\frac{106}{78}$

In table 5 it is shown that the sugar content immediately preceding these tests was lower in each case than in previous determinations. The variation after exercise is less than that between any other two measures except in two cases.

We have no explanation for the fall in sugar content unless it is due to seasonal variation,[3] such as reported by Strouse (12). The blood pressure and urinalysis add little to the interpretations. It might be argued that emotional excitation in preceding determinations influenced the sugar content. That a child should be so much affected in four or six blood tests and not in the next can not be assumed. This fall is noted for the children who had supplementary tests and for those who did not. The preceding activities and breakfasts were approximately the same as in preceding tests.

DISCUSSION AND SUMMARY

The range in chronological age is such as to invalidate direct comparisons of output and changes in sugar content. We give the records to indicate the actual work done by each individual. In the preliminary study of tests for use in this investigation we found a decrease in tapping scores for the fourth period of thirty seconds as compared with the first period. The graphs in figure 6 show this diminished output for each of the nine practice periods. While the decrease fluctuates from day to day, there is no tendency towards a lessening of this difference with increasing practice. Individuals vary as to the period in which least capacity is shown. If a higher level of efficiency is maintained for the first two periods there often results a marked decrease in the third period, with perhaps a slight increase for the fourth or final period. Others show a gradual diminution in capacity from the first to the final period. The fluctuations in the group curves II, III, and IV are probably due to these individual differences.

---

[3] Strouse found that the average blood sugar readings were higher in the cooler part of the year. Daily variations of blood sugar percentage occurred in five normal persons. These variations seem to depend on changes in the weather.

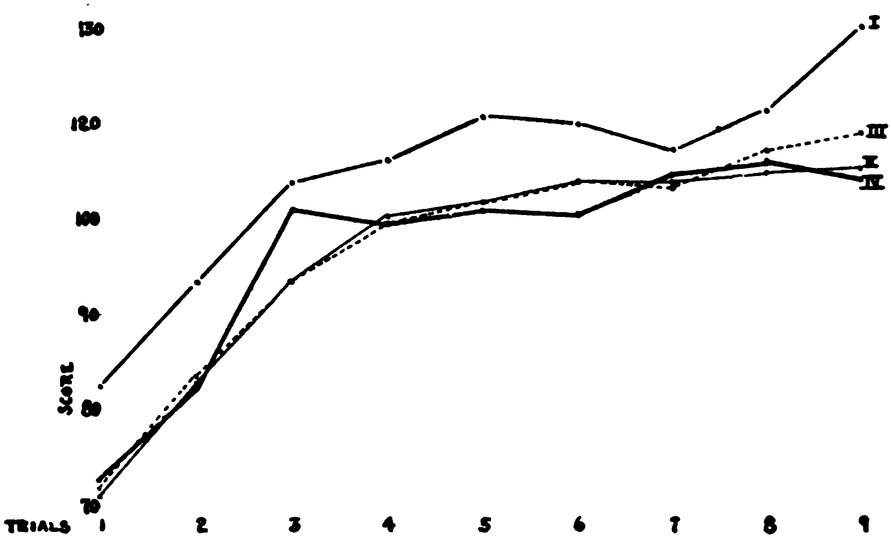


FIG. 6. SHOWING THE DAILY SCORES FOR THIRTY-SECOND PERIODS IN THE TAPPING TEST, ALTERNATE PLATE, FOR NINE CHILDREN

I, Average daily score for first period; II, for second period; III, for third period; IV, for fourth period.

TABLE 6

Individual variations

	FIRST AND SECOND PRELIMINARY	SECOND PRELIMINARY AND BEFORE SERIES I	BEFORE AND AFTER SERIES I	AFTER SERIES I AND BEFORE SERIES II	BEFORE AND AFTER SERIES II	AVERAGE DEVIATION
G. P.	10	10	6	−41	4	14.2
J. S.	−11	2	−5	−35	−2	11.0
D. P.			8	−29	3	13.3
T. F.		6	26	−64	2	24.5
E. C.	−8	0	4	−32	−7	10.2
E. R.	4	−26	30			
J. M.	5	13	2	−30	2	10.4
M. D.	9	25	−3	−41	9	17.4
Average	7.83	11.71	10.5	38.85	4.14	14.43

The individual variations shown in table 6 indicate little stability in blood sugar for a given individual under the conditions of the experiment. We find that a child may show a relatively high sugar content before exercise and either slight or marked increase after exercise. Relatively low content of sugar is also found preceding exercise with a rise of as much as 0.030 after exercise. In some cases a slight decrease is found. We do not know whether such variations are due to a slow rise or to a slow fall in sugar content; to the amount and kind of activity; or to affective factors. Individual E. C., who has been characterized as fearful of slight physical pain and with whom the physician reasoned for some minutes before securing assent to the blood test preceding series I, shows the least average variation. The change in sugar content as shown by determinations made on the same day preceding and after exercise is less on the average than the total group variation. This group average is heavily weighted by the variation in blood sugars obtained April 19, 1921, and May 17, 1921. This we attribute to elevation of temperature. The weather conditions on the days of the experiment were as follows:

	DECEMBER 18, 1920	JANUARY 8, 1921	JANUARY 26, 1921	APRIL 19, 1921	MAY 17, 1921
Temperature at 9 a.m. F.	29.0	39.0	12.0	39.0	48.0
Humidity at 8 a.m.	0.66	0.96	0.52	0.90	0.65
Barometer at 8 a.m.	29.71	29.72	30.45	29.92	30.22

The effects of this seasonal change in sugar content as related to the optimal schedule of activities for school children merits investigation. If we exclude this factor, the change in sugar content for series I, simple muscular exercise, appears more significant. Two children stand out from the group with regard to the internal conditions under which work is performed. In the preliminary practice series for tapping test, alternate plate, the relative capacity of these two children is shown by the following results.

	GROUP	E. R.	T. F.
Average total output	3769.33	3377.00	2552.00
Average daily output	418.80	375.00	364.00
Average for 1st 30 outputs	113.79	99.44	98.00
Average for 4th 30 outputs	100.78	92.55	92.71

It is evident that the stimulating effects of environmental factors are widely different for different children.

Conclusions as to the influence of different kinds and amounts of activities upon the sugar content of the blood would be unwarranted by our data. We believe that they indicate a method of investigation that may clarify the concepts of fatigue and lead to a reformulation of the factors involved in fatigue effects. It seems essential that we make successive determinations throughout a stated period of the day and over a period of time sufficiently long for us to know what the normal changes are for the individuals under observation. Determinations should be made at short intervals preceding and following specific activities which vary in complexity and in motivation.

REFERENCES

(1) **Schneider, E. C., and Havens, L. C.**: Changes in the blood after muscular activity and during training. Amer. Jour. Physiol., 1915, xxxvi, 256.
(2) **Cannon, W. B.**: Bodily changes in pain, hunger, fear and rage, 211.
(3) **Stewart, G. N., and Rogoff, J. M.**: Further observations of relation of adrenals to certain experimental hyperglycemias. Amer. Jour. Physiol., 1920, lvii, 376.
(4) **Bainbridge, F. A.**: The physiology of muscular exercise, 128–138.
(5) **Scott, E. L., and Hastings, A. B.**: A study of the sugar and oxygen relationships in the blood of dogs during exercise. Proc. Soc. Exper. Biol. and Med., 1920, xvii, 120–122.
(6) **Brösamlen, O., and Sterkel, H.**: Der Einfluss von Muskelarbeit auf den Blutzuckergehalt. Deutsches Arch. fur Klin. Med., 1919, cxxx, 360–363, 371–372.
(7) **Johnson, B.**: Practice effects in a target test—a comparative study of groups varying in intelligence. Psychol. Rev., 1919, xxvi, 300–316.
(8) **Woolley, H. T., and Fischer, C. R.**: Mental and physical measurements of working children, 52, 75.
(9) **Dunlap, K.**: Improved form of steadiness tester and tapping plate. Jour. of Exper. Psychol. 1921, vol. IV, 430–432.
(10) **Brösamlen, O., and Sterkel, H.**: *Op. cit.*, p. 360–363.
(11) **Woolley, H. T., and Fischer, C. R.**: *Op. cit.*, p. 123.
(12) **Strouse, S.**: Some variations in normal blood sugar. Archiv. Int. Med., 1920, xxvi, 758.

VOLUME II JUNE, 1922 NUMBER 3

THE JOURNAL OF COMPARATIVE PSYCHOLOGY

Continuing Psychobiology and the
Journal of Animal Behavior

EDITED BY

KNIGHT DUNLAP
Johns Hopkins University

AND

ROBERT M. YERKES
National Research Council

IN ASSOCIATION WITH

MADISON BENTLEY
University of Illinois

HARVEY CARR
University of Chicago

WALTER B. CANNON
Harvard University

RAYMOND DODGE
Wesleyan University

SHEPHERD I. FRANZ
Government Hospital for the Insane

GILBERT V. HAMILTON
Santa Barbara Clinic,
Santa Barbara, California

SAMUEL J. HOLMES
University of California

WALTER S. HUNTER
University of Kansas

HERBERT S. JENNINGS
Johns Hopkins University

GEORGE H. PARKER
Harvard University

EDWARD L. THORNDIKE
Columbia University

MARGARET F. WASHBURN
Vassar College

JOHN B. WATSON
New York City

WILLIAM M. WHEELER
Harvard University

PUBLISHED BI-MONTHLY BY

WILLIAMS & WILKINS COMPANY

BALTIMORE, U. S. A.

Entered as second-class matter April 4, 1921, at the post office at Baltimore, Maryland, under the act of March 3, 1879

Price per volume, net postpaid
- $5.00, United States, Mexico, Cuba
- $5.25, Canada
- $5.50, other countries

Made in United States of America

PSYCHOLOGY CLASSICS

A SERIES OF REPRINTS AND TRANSLATIONS

EDITED BY

KNIGHT DUNLAP
Johns Hopkins University

THE EMOTIONS

BY

CARL GEORG LANGE (1834–1900)
University of Copenhagen

AND

WILLIAM JAMES (1842–1910)
Harvard University

Of interest to Psychologists, Philosophers, Physiologists, and all concerned in mental life

VOLUME I

Pirce, net, postpaid:

$3.50, United States, Mexico, Cuba
$3.75, Canada
$4.00, Other Countries

WILLIAMS & WILKINS COMPANY
Publishers of Scientific Journals and Books
BALTIMORE, U. S. A.

A TENTATIVE CLASSIFICATION OF THE FORMS OF ANIMAL BEHAVIOR

S. J. HOLMES

University of California, Berkeley, California

A classification of the many things which animals do has, I believe, an interest not only for animal psychology but for human psychology as well; and I have therefore attempted to make a grouping of the various forms of animal behavior. What is designated as behavior is not sharply demarcated from the physiological functioning of the body. But while such activities as respiratory movements, sneezing, coughing, etc., may fall under both categories, most behavior is clearly distinguished from physiological functioning as such, although the latter is, of course, involved in behavior as in all the other activities of the organism.

An attempt to group activities, whether internal or external, brings us into contact with problems that differ from those which confront the taxonomic botanist or zoologist. The taxonomist aims to group plants and animals according to a natural system of classification, a system which purports to express the genetic relationships of the organisms with which he deals. The similarities upon which the taxonomist's grouping are founded are, if his classification is a "true" one, based upon community of descent. But the classification of the activities of animals cannot be carried out by simply taking over the methods of the taxonomist. On the other hand, such a classification cannot afford to ignore phylogeny. There is a phylogeny of activity as there is of species and of organs. Just as an organ may become differentiated in the course of evolution into a number of derivative structures, so an activity, such as the functioning of this organ, may become split up into several different modes of action.

There are often features of behavior which are remarkably conservative such as the sucking instinct in the mammalia, but for the most part the comparative psychologist is left without any landmarks analogous to the presence of a notochord or the existence of gill slits which afford so valuable an aid in the search for morphological relationships. Tracing phylogeny, however, is a notoriously precarious business, even for the morphologist with whatever aid may be furnished by paleontology. And when it comes to classifying behavior on a genetic basis, the undertaking is beset with so many additional hazards that it is scarcely practicable in the present state of our knowledge. I have accordingly abandoned the attempt to group animal activities in a strictly genetic system.

The chief difficulties in a genetic grouping of types of behavior is the fact that various activities do not follow diverging paths, each independent of others, as in the case of families and orders of living beings; the activities of any organism are closely interrelated at all stages of evolution. There is frequent change of function which may lead a part originally employed, for instance, in locomotion, to be used at another period for the function of reproduction, as is illustrated in the first abdominal appendages of male decapod crustaceans. Let us consider briefly in this connection the evolution of behavior involved in taking food. Beyond the process of simple absorption such as occurs in plants, the most primitive method of taking in food is amoeboid engulfing which is common among the Sarcodina and in the digestive cells of primitive Metazoa. Sweeping in food by cilia or flagella affords a method of intake prevalent not only in many Protozoa, but widely distributed among lower invertebrates. An advance upon this type is by engulfing food through the muscular apparatus surrounding the oral aperture, an operation often aided by the activity of tentacles (coelenterates). This type of pharyngeal intake is common among coelenterates, flat worms, nemerteans, and many annelids. In the Arthropods we have added to the oral swallowing apparatus a number of organs (mandibles, maxillae and maxillipeds) which, in the Crustacea, are clearly to be regarded as modified locomotor appendages. The derivation of the jaws of vertebrates is less clear. If the lower jaw is serially homologous with the hyoid and branchial arches, its original function may have been respiratory. If so, we have another illustration of the fact that food taking comes to appropriate to itself organs and activities which previously served the interests of other functions. Tracing the evolution of the functions of reproduction we find that a part of this function in the crayfish, for instance, is concerned with appendages originally locomotor. In the course of the elaboration of this function a part of the creature's activities passes at a certain point in evolution from a service of one function into the service of another. In the caphalopod arms, parts of a highly modified molluscan foot (an originally locomotor organ), have come to be largely employed in the capture of food, and in the Decapoda we may have in the peculiar hectocotylized arm of the male a further transformation of function in the interest of reproduction.

These transformations—and they are exceedingly common events in evolutionary history—show us that in attempting to classify the activities of animals on a genetic basis, we cannot proceed as if we were dealing with isolated organisms. It is only through isolation that the usual genetic classification is possible at all. In a genetic classification of organisms the various groups as we trace them back in time fuse into fewer and fewer subdivisions, but in tracing back types of behavior we encounter as it were strands coming in from a variety of sources, combining, segregating and dividing in various ways so that a tree cannot symbolize our system of genetic relationships. Rather we have an intricate network in which there is divergence and convergence all along the course. The situation is somewhat similar to what we encounter in dealing with groups of organisms which freely interbreed. We may have much diversity, a multitude of different types, but no one could work out a strict tree-like classification of such forms. It is only when groups get sufficiently distinct to emancipate themselves from the network of varied hereditary relationships and go on their own independent ways that we can get them placed in a real genetic grouping. Doubtless much of the difficulty encountered in classifying the races of man is due to this fact.

Moreover, in a classification of activities we have perforce to deal with a grouping of performances which are carried on by one and the same animal. This in itself creates many problems quite different from those of the systematist whose task is the proper arrangement of organisms as wholes in a genetic system.

The tentative grouping of animal activities that is here sketched is based in part on the ends subserved by different kinds of behavior and in part on certain general similarities which various kinds of behavior exhibit. Only to a minor extent is any use made of possible genetic affinities of different kinds of activities. The procedure is somewhat akin to what one would follow in essaying a classification of organs or diseases or the occupations followed by human beings. In classifying kinds of behavior one is at liberty to proceed on a number of different principles. Professor Warren in his recent paper has classed reflexes into four groups according to the degree to which they may be modified or inhibited by higher processes. When he passes to instincts he employs a quite different basis of grouping.

Making our primary subdivisions on the basis of the relation of behavior to the welfare of species, we may group activities into (1) those which are adaptive, and (2) those which are not, and the former may be divided into (1*a*) those which are concerned with the preservation of the individual, and (1*b*) those concerned with the perpetuation of the race. Most kinds of behavior which have been recognized and described have in some way or another something to do with the preservation of the species. Mr. Spencer's definition of life as the continuous adjustment of internal relations to external relations, laying emphasis as it does on adjustment (i.e., adaptation) practically ignores the existence of anything in vital activity which does not make either for individual or race preservation. In his interesting but somewhat disappointing chapter on the dynamic element in life in the second edition of his Principles of Biology, Mr. Spencer gives a belated recognition of the inadequacy of his previous formula in that, among other shortcomings, it does not provide for various forms of dysteleological activity. The primary group of dysteleological kinds of behavior is of course a hodge-podge of all sorts of performances resembling each other in nothing except their lack of utility. It is a group recruited from all kinds of behavior, simple and complex, individual and social. Many of the acts in this category are mere aberrant derivatives of purposive acts or acts misdirected or misapplied. Many are the expression of sheer undirected activity. Some acts, like the fits of animals, are pathological. Others may be the expression of old forms of behavior which persist like rudimentary organs under circumstances with which they are not in harmony. Some, like tropistic responses to the electric current and to a less extent other tropisms, may be an incidental result of the creature's organization occurring with no reference to its welfare. A large and instructive treatise might be written on such forms of behavior. Obviously it would be much more voluminous if it included the behavior of man.

The division of purposive behavior into self-maintaining and race-maintaining needs no comment. It is as old as Aristotle and represents a perfectly obvious cleavage, although it is equally obvious that many subordinate activities subserve both ends. Self-maintaining activities are grouped into three divisions, (1) the sustentative which concern themselves with food, water, oxygen, etc., (2) the protective, and (3) the ameliorative. Most animal activities concerned with self preservation are either directed toward securing nutriment or protecting the body from inimical agencies. Nevertheless there is a group of acts which, while promoting life, can scarcely be called protective without extending considerable and perhaps unduly the ordinary meaning of that term. Such performances as sleeping or basking in the sun, if we call these acts, or at any rate such performances as mere exercise and many forms of play are only protective in a very indirect sense, although they may conduce to the preservation of the body. I have accordingly grouped such indirectly preservative acts under a distinct category designated ameliorative. A pig wallowing comfortably in the mud affords a good illustration of behavior coming under this rubric.

Recurring to the sustentative activities, it may be pointed out that these fall into a number of different classes. Oldest,

TABLE 1

General grouping of animal activities

- Behavior
  - Non-adaptive
    - Useless tropistic reactions
    - Misdirected instinct
    - Abnormal sex behavior
    - Pathological activity: fits
    - Useless social activity
    - Superfluous random movements
  - Adaptive
    - Self-maintaining
      - Sustentative
        - Devouring food
        - Discrimination of food
        - Capture of food
        - Activities preparatory to capture as making snares, pitfalls, hunting, stalking
        - Collection of food, digging, boring, gnawing
        - Migration
        - Caring for food for future use, hiding, burying, storing
        - Preparation of food
      - Protective
        - Against enemies (see table 2)
        - Against inanimate forces, reactions to heat, light, gravity, chemicals, etc.
        - Against inanimate objects, i.e., avoidance of moving objects, cleaning movements, etc.
      - Ameliorative
        - Rest, sleep, exercise, play, basking.
    - Race-maintaining
      - Sexual behavior
        - Of male toward female:
          - Copulation
          - Sex discrimination, seeking the female
          - Courtship, sex calls
          - Battling for female
        - Of female toward male,
          - Resisting, accepting alluring, coyness
      - Parental behavior (see table 3)
        - Parents toward offspring
        - Offspring toward parents
      - Social behavior (see table 4)
        - Sustentative
        - Protective
        - Ameliorative

phylogenetically, are the movements directly concerned with taking in or swallowing food. As animals become more highly developed, we meet with an elaboration of preparatory or subsidiary actions. Thus associated with taking in food are acts which bring the organism in contact with food, and acts which involve a discrimination between what serves as food and what does not. In many animals taking in food is preceded by capturing or overcoming some other organisms, or by other activities such as digging, boring or gnawing. In higher forms, especially, activities accessory to these are added such as hunting, making snares or lying in wait. In exceptional cases there may be storing of food, as in rodents, many bees, and some species of ants. Even more elaborate behavior is occasionally developed, as shown in leaf-cutting ants, which devour fungi grown upon the prepared leaves which are carried to the nest. The elaboration of activities of varying degrees of indirectness which are subsidiary to food taking would afford an interesting phylogenic enquiry to which we can do no more here than simply call attention.

Protective activities may be grouped into those concerned with general forces such as heat, light, gravity, etc., and those concerned with definite objects. Under the former come most of the forms of behavior commonly called tropisms, in so far as these are directly or indirectly subservient to life. For most purposes of analysis, however, it is doubtless most advantageous to consider tropisms as general modes of response quite regardless of their utility.

Reactions of a protective nature directed to specific objects are common and fall quite naturally into two groups: (1) those in relation to living objects, usually enemies, and (2) those in relation to objects which are not living. Protection from enemies may be secured (*a*) through escaping from them by some means, or (*b*) by standing ground and making some defense. Defense may be accomplished by (*b*1) offering passive resistance such as closing a shell, erecting spines, or otherwise rendering the animal difficult to attack. Or (*b*2) an animal may defend itself by actively inflicting some injury on its assailant. Primarily such active defense consists in retaliatory infliction of injury after attack. But in some cases, especially in higher forms, we meet with an aggressive pugnacity which does not wait for an attack to be made, but incites to attacks which are apparently unprovoked. The function of such gratuitous hostility is, however, primarily protective. It is often advantageous to take the offensive against a potential enemy. Animals which are particularly irascible are often given a wide berth and this often means the undisputed possession of many desirable things. To a certain extent, also, aggressive pugnacity may be the expression of the fighting instinct which, if it does not find sufficient exercise through provocation, may tend to discharge itself without the usual stimulus.

TABLE 2

Forms of self-maintaining protective behavior toward enemies

Protective behavior against enemies	By escape	Flight		
		Death feigning		
		Deceptive quiet		
		Hiding		
		Disguising, emitting ink		
		Changing color		
		Making protective habitats, holes, etc.		
	By defense	Passive	Closure of shell or habitation	
			Rolling up (pill bugs, armadillo)	
			Erecting spines	
			Emitting odors	
		Active	Retaliatory	Biting, clawing
				Kicking, stinging
				Hunting parasites
				Fighting plays
			Anticipatory	Same acts that fall under retaliatory defense

Along with active defense should be placed playful or make-believe fighting which is so common among higher animals and which may be regarded, in accord with the theory of Groos, as preparatory to serious encounters.

Activities directly or indirectly subservient to race maintenance form a large and varied group. Obviously, they include (first), sex behavior, and (second) parental care, and I have also placed (third) social behavior under this head because such behavior, while often subserving the interest of the individual, is primarily of service to the group and much of it is probably derived phylogenetically from activities concerned with the maintenance of the family. Sex behavior is devoted to the end of securing the meeting of ova and spermatozoa. It emerges gradually from the simple physiological functions of forming and discharging the sex cells. There is no sex behavior properly so-called in sponges, coelenterates, echinoderms, many mollusks (such as lamellibranchs) and various other invertebrates which simply discharge their sex cells into the water and leave their meeting to chance. In some of the Protozoa we may have sex behavior involved in conjugation, the relation of which to the behavior of gametes in multicellular organisms we shall not here discuss. Some of the invertebrates discharge their sex cells under the stimulus afforded by the proximity of the other sex and in animals in which internal fertilization does not occur we often find strong instincts leading to a close association of the sexes and a simultaneous discharge of the sex cells during the breeding season as in many fishes. In some animals that discharge their sex into the water, proximity is insured by the development of instincts of the male to seize and retain the female as in frogs and toads. Association of the sexes, whether it involves internal fertilization and the consequent development of copulation, or whether it involves the delicate responsiveness insuring the simultaneous discharge of sex products into the water, entails the development of the power of sex recognition and activities on the part of the males for seeking and seizing the females. Such a procedure involves a whole stream of accessory activities which have been of the greatest importance in the evolution of behavior. Courtship, the song of birds, battles on the part of males for the possession of females with the accompanying evolution of larger size, strength, weapons of defense and pugnacity in the male sex, are among the many subsidiary developments which have gradually been added to the primary function of sex. The evolution of sex behavior, although most conspicuous in the male, has had its complementary counterparts in the female sex in the development of various instincts such as coyness and alluring instincts, as well as other acts more closely associated with the propagation of the species.

The category of parental behavior is used in a broad sense to include not only the behavior of parents toward offspring but the reactions of offspring to parents, and, in the former case, the behavior of parents not only toward young, but in relation to the eggs from which the young are to emerge. Behavior toward eggs includes the activities of egg laying, protecting and incubating eggs, nest building, selecting a site for eggs and often providing food for larvae to which the eggs will give rise. As I have elsewhere attempted to show,[1] care for young first developed by extending care directed to eggs to what comes out of the eggs. And when this step is taken a line of evolution is entered upon which has led not only to greater and greater extensions and elaborations of parental care, but also to the various forms of social behavior.

As the care for offspring has evolved there has been a coordinate development of behavior of the young towards their parents. Following, cuddling, making cries, obeying signals, such as the danger chirr of the domestic hen, and imitation are among the acts by which the young derive benefit from the association with their parents, and many of these acts come, in time, to have a significance in social life far beyond the limits of the family group.

Social behavior, like self-maintaining behavior, I have divided into the sustentative, the protective and the ameliorative. There are sustentative activities which are social, such as mutual feeding among ants, bees and termites, collecting, preparing and storing food for the group, leading others to food, as in ants, and group attacks upon prey, as in packs of wolves. But most social behavior is primarily protective. And protective social behavior, like protective individual behavior, is directed (1) toward inanimate forces and objects on the one hand, and

---

[1] Studies in Animal Behavior. Ch. 2. The Evolution of Parental Care.

(2) toward animate creatures, largely in the form of enemies, on the other. Under the first there is the construction of common habitations or other means of shelter against the elements, and keeping the habitation clean (as in ants and bees). The chief protective efforts of animals, however, are concerned with other living creatures. The most primitive exhibition of such behavior is direct, cooperative defense against an attacking enemy. Shelter making is often more for defence against enemies than for

TABLE 3

Forms of parental behavior

Parental behavior	Parents toward offspring	Egg laying	Oviposition
			Selecting suitable places or hosts (as in parasites)
			Preparation of places for eggs
		Nest building, hole digging	
		Incubation	
		Provisioning eggs	
		Protecting eggs, nest, or young	Concealing
			Brooding
			Carrying eggs or young
			Decoying away enemies
			Fighting enemies
			Keeping eggs or young in optimum temperature, moisture, etc.
		Feeding young	
		Cleaning young or nest	
		Training young	
	Offspring toward parents	Feeding, sucking, response to parental feeding	
		Clinging	
		Cuddling	
		Making cries	
		Following	
		Obeying calls	
		Imitation	

protection from the elements. Coöperative offensive undertakings naturally grow out of defensive efforts as in individual behavior and may likewise be regarded as primarily anticipatory defense. Actions subsidiary to defense naturally assume importance as life becomes more complex. We see the development of warning behavior, danger cries, the posting of sentinels, and the communication of a hostile attitude by the spread of the angry hum in a hive of bees.

TABLE 4

Classification of the forms of social behavior

Sustentative	Mutual feeding (feeding of queens and drones)		
	Coöperative food getting		By discovery of food and communication. By overcoming prey
	Food storing		
	Food preparing (leaf cutting ants, honey ants)		
Protective	Against inanimate forces or objects		Mutual shelter making and seeking Mutual cleaning and habitat cleaning Huddling together for warmth
	Against enemies	Direct	Shelter making Mutual warning by cries and acts, sentinel posting Coöperative defense Coöperative offensive attacks (anticipatory defense)
		Indirect	Social play, music Social self assertion, pride, showing off, domineering Social subordination, following, bashfulness, modesty Communication Imitation Suppressing the egregious Manifestations of sympathy and affection
Ameliorative	Many social plays and amusements Music Aesthetic activity		

Besides the defensive actions of social animals and the actions immediately subservient to the function of protection, there is a large class of social activities whose connection with defense is quite indirect but whose *raison d'être* is nevertheless to be found, at least in part, in their subservience to this end. The instincts which make for social subordination such as bashfulness, the tendency to attack or suppress the egregious, sequacity, and to a certain extent imitation, make indirectly for the solidarity of the group upon which successful defense often depends. Mutual aid and the sympathy by which in higher forms such aid is prompted, as well as many of the play activities of social animals contribute also to the same end. On the other hand, we have the instinctive exhibition of pride, self assertion, the tendency to dominate and assume leadership entering, along with apparently opposite or contradictory traits, into the composition of the higher animals and man. I shall not discuss the interesting problem of how far the original nature of man can be interpreted from the standpoint of adaptive responses. There is in all animals, and possibly to a relatively large extent in human beings, an ingredient of biologically nonsignificant behavior. How large is this ingredient of undisciplined activity which has never been worked in for military service is difficult to determine. The Darwinian must agree with the dictum of Schiller, "Ernst ist das Leben,"—life is serious business. But while life is ever devoted to its own maintenance, to a considerable and not accurately determined extent it indulges in just frills. The Darwinians may argue, often with reason, that what appear to be just frills have nevertheless their indirect utility. The Groos theory of play would reduce the most wanton gambols of young lambs to preparation for the serious business of later life. Even our social plays and sports may prepare for social life and tend to promote social solidarity. But even accepting such an interpretation of play as valid, it can at least represent but a general truth. Just as naturalists are coming to regard many of the specific characteristics of organisms of no utility, so there are many acts which have no biological value or are even injurious. And when we come to interpret the behavior of human beings in relation to a physical and social environment that is ever changing, it is obvious, I believe, that such behavior should become much more common.

To a larger extent than obtains in lower forms, perhaps, social behavior in higher animals, and especially in man, may be described as ameliorative, although it is always difficult to draw a distinction between this category and acts which are indirectly protective. Much of human social behavior, when it has any biological significance at all, is not directed toward preparing, even in sport, for any particular defensive action. Our various forms of amusement, so far as they can be said to enhance life, have a general rather than a specific benefit. The same is probably true, although to a less extent, of the social plays of animals.

The foregoing classification of animal activities is confessedly imperfect in many ways. It presents only one system of grouping out of many which might be devised and which may have their special advantages. The attempt to class forms of behavior naturally suggests many problems of derivation of forms of activity. It is perhaps useful in aiding us to gain a comprehensive view of animal activities; it may help us to conceive how they have unfolded, how accessory activities have been added to primitive ones, and to understand how forms of behavior have become interrelated in various ways in the course of evolution.

THE ABILITY OF MUDMINNOWS TO FORM ASSOCIATIONS WITH SOUNDS

FLORENCE WESTERFIELD
Zoological Laboratory, University of Wisconsin

Parker (1903, 1918) showed that fishes receive stimuli from sound vibrations; that vibrations at very slow rates stimulate the lateral line organs and that more rapid vibrations stimulate the ear. Washburn and Bentley (1904), and White (1919) demonstrated that chubs, mudminnows and sticklebacks can form associations with particular colors and the latter investigator has recently proved that such discriminations are to be definitely referred to particular vibrations (colors) and not to intensity differences.

Mudminnows Umbia limi (Kirtland), and sticklebacks, Eucalia inconstans (Kirtland) depend largely on the sense of sight in their ordinary activities, but the writer made preliminary tests which indicated that these fishes react readily to sounds, and was able later to show that the mudminnow is able to form associations with particular tones. This paper describes experiments in which mudminnows learned to associate a high tone with a distasteful flavor and a low tone with food. Similar experiments were tried with sticklebacks by another person in this laboratory, but these fishes never learned to leave the unpalatable baits alone. They soon became very tame and jumped after everything that was offered to them. Sometimes they even pursued and swallowed unpalatable objects that they had just taken into their mouths and rejected. As the experiments with sticklebacks gave no positive evidence of ability to form associations with sounds, they are not described.

On October 1, 1921, ten mudminnows were brought into the laboratory and placed in separate battery jars (diameter 15 cm.; height 20 cm.), which were arranged in a row on a long table against a wall. A thick piece of corrugated paper was placed beneath each jar, in order to prevent the ready transmission of vibrations from the table to the jars and vice versa. Two of the minnows died during the first week, but the other eight remained in good condition until after January 1, 1922.

From October 1 until December 21 the minnows were fed every day, except Sundays, with bits of snail offered to them on a pair of forceps. Before each fish was fed a cardboard cylinder was placed around the jar in which it was kept, so it could not see what was to be offered on the forceps. Before feeding, the base of a ukelele was placed against the jar through an oblong slit in the cardboard. Before and while the food was offered a low note (low D; 288 vibrations per second) was sounded several times. The base of the instrument completely closed the aperture; thus making it impossible for the fish to see its surroundings and giving a good contact against the glass wall of the jaw. Each fish was given one piece of snail each day. All soon became tame and learned to leap about a centimeter out of water to take food from the forceps.

After November 8, each fish was daily given two opportunities to take objects from the forceps. For one trial a piece of fresh snail was offered; for the other, a piece of gray paper. The paper resembled a piece of snail in color and general appearance and had been soaked in spirits of camphor. After December 1, one minute was allowed for each fish to take or refuse the object offered. The order in which food and camphor-soaked paper were offered was varied from day to day. Whenever the paper was offered a high string on the ukelele was sounded (pitch, middle A; 426 vibrations per second).

After November 8, each fish could make two mistakes each day—it might refuse the food or take the paper. At the end of the experiments (December 21, 22, 23) food was offered when the high string was sounded and paper when the low string was sounded—thus reversing the signals to which the fishes had been trained. Fishes numbered 1 and 2 did not appear to learn as well as the others, but it was discovered on December 14 that the papers below their jars had warped so that the base of the

TABLE 1

Errors made by eight mudminnows. Fed snail meat with low tone from October 1 to December 20, and camphor-soaked paper with high tone from November 8 to December 20. Fed camphor-soaked paper on low tone and snail meat on high tone on December 21, 22, 23

NUMBER OF FISH	1	2	3	4	5	6	7	9	TOTAL	PER CENT ERROR
October 1	0	1	1	0	1	0	1	0	4	50
October 3	1	1	1	0	1	1	0	0	5	62
October 4	1	1	0	1	0	1	0	0	4	50
October 5	1	0	0	0	0	0	0	0	1	88
October 6	0	0	0	1	0	0	0	0	1	88
October 7	0	0	0	1	0	0	0	0	1	88
October 8	0	0	1	0	0	0	0	0	1	88
October 10	0	0	1	0	0	0	0	0	1	88
October 11–15	0	0	0	0	0	0	0	0	0	0
October 17	0	1	0	0	0	0	0	0	1	88
October 18–31	0	0	0	0	0	0	0	0	0	0
November 1– 8	0	0	0	0	0	0	0	0	0	0
November 1– 8	1	0	0	0	0	0	1	1	3	3
November 9	0	1	0	0	0	1	0	1	3	19
November 10	0	1	0	1	1	1	1	0	5	33
November 12	0	0	0	0	0	0	0	1	1	6
November 14	1	0	0	0	0	0	0	1	2	13
November 15	1	0	1	1	2	0	0	0	5	33
November 16	0	0	1	1	0	0	0	1	3	20
November 17	1	0	0	1	2	1	0	0	5	33
November 18	2	0	1	0	0	1	1	0	5	33
November 19	0	0	0	0	0	1	0	0	1	6
November 21	0	0	1	0	0	0	1	0	2	23
November 22	0	1	0	1	0	0	0	0	2	14
November 23	0	1	0	0	0	0	0	1	2	14
November 25	0	1	1	1	0	0	1	0	4	27
November 26	0	0	0	0	0	0	0	0	0	0
November 28	0	0	1	0	0	0	0	0	1	6
November 30	0	1	0	0	0	0	0	0	1	6
December 1	0	0	0	0	0	0	0	0	0	0
December 2	1	1	0	0	0	0	0	0	2	13
December 3	2	1	0	0	0	0	0	0	3	20
December 5	0	0	0	1	0	0	0	0	1	6
December 7	0	0	0	0	0	0	0	0	0	0
December 8	0	0	0	1	1	0	0	0	2	13
December 9	1	1	0	0	0	0	0	0	2	13
December 10	1	1	0	0	0	0	0	0	2	13
December 12	0	1	0	0	0	0	0	0	1	6
December 13	0	0	0	0	0	0	0	0	0	0
December 14	1	1	0	0	0	0	0	0	2	13
December 15	1	1	0	0	0	0	0	0	2	13
December 16	1	1	0	0	0	0	0	0	2	13
December 17	0	0	0	0	0	1	0	0	1	6
December 19	0	0	0	0	0	1	0	0	1	6
December 20	0	0	0	0	0	0	0	0	0	0
December 21	2	2	2	2	2	2	2	2	16	100
December 22	2	2	2	2	2	2	2	2	16	100
December 23	2	2	2	2	2	2	2	2	16	100

ukelele was prevented from making a good contact with the glass. After this defect was corrected, these two fishes made better records.

Table 1 summarizes the results of the experiments. There seems to be no doubt that all of the fishes learned to associate the high tone with camphor-soaked paper and the low tone with snail. This is rendered more certain by the behavior of the fishes after December 20, i.e., after the sounds associated with food and paper had been reversed. The fishes continued to respond as they had been taught to do, though their behavior was then "wrong" for securing food.

The conclusion appears to be warranted that mudminnows are able to form associations with sound vibrations.

REFERENCES

PARKER, G. H. 1903 Hearing and allied senses in fishes. Bull. U. S. Bur. Fish., xxii, 45–64.

PARKER, G. H. 1918 A critical survey of the sense of hearing in fishes. Proc. Amer. Phil. Soc., xlvii, 1–30.

WASHBURN, M. F., AND BENTLEY, I. M. 1906 The establishment of an association involving color discrimination in the creek chub, Semotilus atromaculatus. J. Comp. Neurol. and Psychol., xvi, 113–125.

WHITE, G. M. 1919 Association and color discrimination in mudminnows and sticklebacks. Jour. Exper. Zoöl., xxvii, 443–498.

ABILITY OF PIMEPHALES NOTATUS TO FORM ASSOCIATIONS WITH SOUND VIBRATIONS

HELEN E. McDONALD

Zoological Laboratory, University of Wisconsin

Several blunt-nosed minnows, *Pimephales notatus* (Rafinesque), were brought into the laboratory on November 29, 1921, and kept for several weeks before they were subjected to experiment. Their average length was 1½ inches. In nature these minnows are hardy and show considerable adaptibility to different habitats, and great variety in their food. They are very alert, quick in their movements, and seem to make constant use of the sense of sight, both in escaping danger and in obtaining food. They show a pronounced tendency to form schools. Those in the laboratory moved about together in the aquarium. For this reason it was decided to use an experiment that would involve the group as a whole, in order to test the ability of the minnows to form associations.

An aquarium that measured 18 inches long, 10 inches wide, and 13 inches deep (inside) was filled with water to a height of 9 inches. The two ends were of wood, while the sides were of glass. A bass viol string was stretched lengthwise across the top on one side and fastened securely at both ends. A device for tuning the string made it possible to keep it tuned to G below C on the bass cleft, and thus a frequency of ninety-six vibrations per second was maintained. A cardboard was placed over the top of the aquarium, just beneath the string, to prevent the minnows from seeing the vibrating string, or the experimenter, and thus the possibility of the fishes forming an association by means of sight was eliminated. The wood to which the string was attached vibrated with the same frequency as the string, and these vibrations were communicated directly to the water. A small hole, measuring 2½ inches in diameter, was cut in the cardboard.

The purpose of the experiment was to see if blunt-nosed minnows could be trained to come to the opening in response to the vibrations. Bits of finely chopped clam meat were fed to them immediately after the string was made to vibrate.

Six minnows were chosen and placed in the aquarium several days before the period of training began (January 2, 1922). For the first few days the fishes responded to a fairly strong vibration by darting to the bottom of the aquarium and remaining there for several minutes before again venturing near the surface. Food, dropped through the opening immediately after the vibrating of the string, was allowed to reach the bottom of the aquarium before being seized by the fishes. After two weeks of daily training the minnows had changed their first reaction, and in response to the vibrations they would dart quickly to the surface of the water in the corner just beneath the opening in the cardboard, eagerly awaiting bits of food.

Every precaution was taken to prevent the minnows from seeing the person who vibrated the string and dropped the food into the aquarium. After the association was formed, the food was never put into the aquarium until the fishes had responded to the vibrations by coming to the surface. To prevent the possibility of shadows influencing the action of the fishes, an artificial light was suspended directly over the aquarium.

This experiment indicates that the blunt-nosed minnow is able to form an association with sound vibrations.

No effort was made to determine whether the stimulus was received through the skin, the lateral line, or the inner ear. All three of these organs may act as receptors for the vibrations. It seems probable that the association was formed with the sound, and that the inner ear was the receptor involved. This conclusion appears to be justified on account of the results of experimental work by Parker[1] on Fundulus. This investigator found three receptors for vibratory stimuli in fishes and concluded that the function of the lateral line is to perceive slow, mass movements of the water, while the skin is influenced by surface waves or ripples, and that the ear receives sound vibrations. He came to the last conclusion because he noted that the fishes reacted before waves set up by the vibration of such a string as was used in the present experiment had time to reach them. The quickness of the reactions of the blunt-nosed minnows, and their responses when at such depths as to be below the action of surface waves, indicates that these fishes possess a sense of hearing and are capable of forming associations by means of that sense.

---

[1] Parker, H. G. 1903 Hearing and allied senses in fishes. Bull. U. S. Fish. Comm., xxii, 45–62; also 1918 A critical survey of the sense of hearing in fishes. Proc. Amer. Phil. Soc., xlvii, 1–30.

THE INTEGRATIVE CHARACTER OF HABITS

J. R. KANTOR

University of Indiana

Among the indications that psychology is making headway in the understanding and solution of some of its intriguing but no less difficult problems stands prominently the fact that the psychologist is broadening his perspective and withdrawing from the narrowness which the physiological ancestry of psychology has bequeathed to him. Signs multiply that psychologists are beginning to admit into their purview many of the larger forms of psychological phenomena which we may designate as social reactions, and what is equally important they are taking a keener interest in the larger and more complex individual reactions that are usually spoken of under the heading of abnormal and pathological behavior. In general, we might say that psychology is opening its doors to broader and perhaps more significant problems and is no longer circumscribing its activities by physiological boundaries which limited its studies almost wholly to sensory reactions.

One of the most striking facts correlated with this enlarging attitude of psychologists appears to the writer to be the growing appreciation of the place stimuli take in the operation of psychological phenomena. And by stimuli we must mean here actual objects and conditions with which are integrated both our simple and complex reactions. For only when we eschew the traditional fallacy that the stimuli to our actions are merely light rays or sound waves can we hope to understand the complex interactions of the psychological organism with its surrounding objects. Now when we look upon psychological phenomena as coördinations of responses and stimuli the domain of psychological observation is unlimited; we may study any kind of reaction of the person whether it be simple or complex, physical, social, aesthetic or intellectual, whether it be normal or pathologic. Standing upon this kind of platform we may hope to study the psychological process of, say, reasoning as an actual response to social and cultural situations and not be content with repeating the fruitless abstractions of what is supposed to be logic. And to mention another illustration, when we look upon psychological phenomena as responses to actual stimuli we can then study such constant phenomena as sleep and dreams with some hope of understanding them instead of throwing them out of the domain of psychology as abnormal. Also, language need no longer stand as an unwelcome stranger at the gates of psychology but may be admitted into its domain as genuine data capable of being analyzed and interpreted. In short, we may say that a concrete study of stimulating conditions as phases of such phenomena must rob of its sting the accusation made against the psychologist that he does not consider himself a scientist until he has destroyed the living, pulsating and striving thing that is man.

More especially are we interested at present in pointing out the advantage to psychology of including the stimuli when we are trying to understand the type of behavior we have learned to know as habits. Consider for a moment what the traditional physiological psychology has done with habits. In the first place, because psychological phenomena are presumed to be the mere operation of physiological structures, habit responses are believed to comprise only a few overt actions. Secondly, these habits are thought of as governed or made to operate in some manner by so-called lower brain centers which have no part in the acquisition of the reactions but take over the "control" from the higher brain centers, which operated during the formation of the habits. Contrariwise, when we consider habits to be the reactions of a person to definite objects and conditions about him we can not limit them merely to simple overt responses but must take account of all the varieties of habit responses which we can observe ourselves to have, besides understanding the conditions under which they are formed and the manner in which they operate after we acquire them.

Howsoever humiliating it may be to the technical psychologist it is still true that much of the impetus responsible for the growing appreciation of the place of stimuli in psychological phenomena has been derived from the study and the interpretations of the psychopathologists. They it was who, working with persons whose behavior was conditioned by some untoward condition in the surroundings, had to take account of those surroundings in their endeavor to improve the behavior of the abnormal individual. As a record of fact, the unbiased studies of the psychopathologists yield us much information concerning the complexity of our physical and social stimuli.

But when we accord the psychopathologist his full meed of credit for bringing to our attention the rôle of stimuli in the operation of our reactions let us observe that we do not thereby in the least detract from the value of the technical psychologist's work in this direction. For this emphasis upon the rôle of stimuli in psychological phenomena is to a great extent the outcome of the psychologist's changing attitude toward the character of psychological data.

To say the least, it is being more and more appreciated that psychological reactions are not merely psychical elements, or in the case of habits merely the organization of neural elements (the earthly surrogates of psychic states) but rather that all actions are complex operations of persons. This objective interpretation of psychological phenomena forces us to correlate the individual's responses with other facts connected with them. Thus, we find that the observations of psychologists themselves have led to the view that stimuli conditions are important in the study of human behavior, and this recognition is entirely in addition to the intellectual support of this view derived from the work of the psychopathologists. To the writer this dual origin of our interest in the stimulating circumstances of behavior seems most significant because it lends support to the correctness of the view that such circumstances cannot be omitted from an accurate study of our actions.

And now we come to the purpose of this paper. It is, namely, an attempt to interpret habit responses in such a way that we will both do justice to the description of the response factors and at the same time connect them with their stimulating auspices. For we believe that the fundamental character of a habit response is precisely the manner in which it is connected with its stimulus. To us it seems that a thoroughgoing study of habits in this way would yield up much of the secret which psychologists now consider a veiled mystery concerning the nature of habit formation. Is not this mystery essentially inherent in the view that the formation of habits is due to some hidden processes in the neural apparatus or at least in some physiological "basis"? As a provisional study of the stimulus-response nature of habit reactions we are offering the following discussion.

I. THE GENERAL NATURE OF HABITS

Habit reactions constitute in their widest phases specific forms of intimate connections between behavior adjustments and particular stimuli objects and conditions. Through repeated contacts of specific responses with sundry particular objects, persons and circumstances, the former in the course of time become practically inseparably integrated with their specific stimuli.[1] As a consequence, we find that in some cases of simple behavior, habit reactions are automatized actions, since the process of integration results in a minimization of the challenge which an unintegrated stimulus usually offers the individual. Because the person has developed a large number of such intimate integrations of stimuli and responses the mere presence of the stimuli call forth the correlated responses and consequently it appears that the person is conditioned or guided by the stimuli in such a way that he is enabled to respond more readily and definitely to his various surroundings. In other and more complex situations the integration of responses and stimuli serve not to provide the organism with automatized acts but rather with specialized behavior equipment for complex stimulating conditions.

Habits, then, in their broader aspects are describable as forms of action which appear to place the organism *en rapport* with surrounding objects and result in an ease of adjustment which could only be brought about by the development of an intimate relationship between responses and stimuli. We may look upon habit responses, therefore, as involving specialized forms of the associational processes, in which reactions are intimately interconnected with specific objects and other forms of stimuli.

---

[1] A similar integration hypothesis is suggested by Holt, The Freudian Wish, 1915, p. 189.

Need we say that habit reactions are active positive processes and not merely the passive conformity of the person to his surroundings? That is to say, the fact of having a habit does not mean undergoing a change that will make us fit into our surroundings. The psychological fact of habit is not at all a passive change as in a garment which fits better after being worn or a lock which works better after being used. Such presumed analogies do not touch the problem of habits in the least, as James seemed to think.

But if the habit situation is an active one, in what consists the activity? We answer, as we have so many times repeated, in the organization of specific responses to specific stimuli. The emphasis is always and foremost upon the fact of integration and not upon any change in the individual, although as we shall see the possession of an equipment of habits naturally means always decided changes in the person. Indeed when we learn what a person's habit equipment is we are in a fair way to understanding him and to predicting how he will act under given stimulating circumstances.

Let us be carefully warned at once that our conception of habits as the integration of specific responses with particular objects and conditions precludes and invalidates the mistaken notion frequently exploited that habits constitute a general type of acquired reactions, and that the term habit merely contrasts with the term native, the symbol for unlearned reactions. This is not so in fact, for certainly it is true that an equal number of our reactions, the acquisition of which no one can doubt, are not correctly described as merely intimate integrations of responses and stimuli, a description which does mark habits. Here we might mention thought and feeling reactions of all sorts, many skill responses and language activities. When we make all acquired reactions into habits do we not unduly efface the difference between our reactions and make of habit merely a term to stand for the fact that reactions are acquired? Twofold is our objection to such a view. In the first place, it involves a radically false assumption concerning the inheritance of actions, and in the second place, it overlooks the fact that habit reactions are definite and specific forms of reaction systems, that is to say habits constitute a particular group of reactions. If we care at all to trace the source of this mistaken identification of all acquired behavior as habit responses we may find it in the acknowledged fact that habit reactions do not, as some of our simpler reactions do, involve a very close dependence upon the organic constitution of the individual. This source, rooted in fact as it may be, does not in the least provide an adequate justification for the attitude that all responses called acquired are habits.

Another reason we may discover for the contention that all acquired responses answer to the same description as habits is that the acquisition of habit responses does undoubtedly presuppose a fair amount of behavior equipment already possessed by the person. But this indubitable fact in no wise means or implies that the reactions comprising that already possessed equipment are not themselves entirely or mainly acquired. It is this latter case that we take to be the fact, and we need only add that this already possessed equipment may consist of habits as well as of many other kinds of reaction systems.

Very important is the characteristic of habit responses which may best be described as that of the practically non-transformation of the stimulating objects and circumstances. Let us recall again that the significant feature of the entire habit situation is the interconnection of a response and a stimulus; so it is not surprising that aside from the case in which the stimulus is an endogenous reflex of the individual no change or increase in the object or other stimulating situation occurs either when the habit is built up or when it operates later.

II. THE FUNDAMENTAL PSYCHOLOGICAL BASIS OF HABITS

Habit reactions have their basis primarily in two fundamental characteristics of psychological phenomena, namely, (1) differentiation and (2) integration of behavior.

1. Differentiation of behavior means that every psychological act consists of a differential response of the organism to some specific object or other stimulus factor. Essentially, the point is that no psychological fact can be thought of as consisting exclusively of the reaction phases of adjustments but must always include also the stimulus factor. The actual unit of psychological phenomena, in other words, consists of a definite response and a stimulus. This means that the psychological individual builds up specific responses to concrete stimuli which operate when those stimuli are presented, unless the response is delayed or inhibited. Now habit responses represent an intensive form of such differential connections between responses and stimuli. Intensive connection we say because there is in the habit situation not only this connection between a response and a stimulus but a practically fatalistic operation of the response when the stimulus is presented. Possibly it is not inappropriate to suggest that the acquisition of habit responses is equivalent to a minimization of the chances for inhibition and delay of the responses in the presence of their coördinated stimuli.

2. The second psychological condition in which habits are rooted is the property of integration by which is meant the morphological organization of reaction systems of which the product is a more complex and adaptable reaction unit. In two ways is the condition of integration operative in the habit situation. First, directly in the organization of more complex reaction systems from simpler ones, a process which is of no slight importance in the development of habit responses, since the integration of responses with stimuli frequently involves considerable development and expansion of reaction systems. Especially noticeable is this situation in the organization of typewriting, swimming, and other primarily manual activities. In the second place, the integration process is of great importance in habit

formation in an indirect way, namely, as a prominent process in psychological association. Now one of the primary forms of psychological association consists in the process whereby responses are connected with stimuli, and some forms of these associational connections we may well call habits.

In detail, the habit forms of association are such close associations of response patterns and stimuli that not only are the various member reaction systems integrated into a unit, but this pattern as a unit of response appears also to be very closely integrated with the stimulus, so that the whole behavior fact becomes an indivisible unitary process. Upon the closeness of this integration of the members of the behavior pattern, and the whole pattern with the stimulus can we differentiate between degree classes of habits, the limiting point being such a loose connection that the segment of behavior can no longer be called a habit action. And thus one of the incidental results derived from our study of the psychological basis of habit responses is a touchstone by which to distinguish habit behavior segments from other types. This characterization of habit behavior segments we shall discuss in the next two sections.

III. THE CHARACTER OF HABIT BEHAVIOR SEGMENTS

According to the typical description of habit reactions, they are in terms of behavior segments, simple final responses to stimuli; in fact they are discussed much in the fashion of reflexes, excepting of course that the former are always assumed to be acquired. Just why habit actions should be aligned with reflexes is found in the traditional psychological belief that habit actions when acquired involve few or no mental factors but are the operation of various organizations of muscular apparatus. Connected with this belief and possibly as a result of it the view has flourished that habits are exclusively manual actions of various sorts. In consequence, psychologists following James undertook at one stroke to describe and account for habits in terms of neural connections much as they did in the case of reflexes, with this difference, of course, that in the case of habits the neural connections were presumed to be located in the so-called higher and lower centers of the brain instead of in the spinal cord. Now we on the contrary unhesitatingly believe that such a method of describing habit action is contrary to the actual facts, resulting as it does in an unwarranted abridgment of the classes of habits, and worse, it leads to an inadequate description of any type of individual habit act. Accordingly, we propose in the present section to examine the typical habit behavior segments in their response phases, reserving for a later section the study of the stimuli factors.

When we examine a habit behavior segment it goes without saying that whatever we may mean by conscious or mental factors they cannot be lacking in habit reactions for such reactions are very definitely differential responses to specific stimuli. And this differential process we assume to cover the part of consciousness or awareness.[2] Moreover, in considering the details of behavior segments in the case of habits on the response side they comprise a great variety of reaction patterns differing in morphological character and in degree of complexity. Now since every response pattern involves both precurrent and final reaction systems it cannot be true that habits are exclusively final or motor adjustments. How this error is made may be easily accounted for by the fact that since the habit behavior segment represents so intricately organized a response to a stimulus the precurrent phases may be easily overlooked. Certain it is, nevertheless, that habit responses may and frequently do involve the operation of a very elaborate pattern of precurrent activities before the final response occurs. Possibly this situation is very well illustrated by language activities in which the unit of response is a pattern (sentence) of which the last element (word) only may be considered as the final response.

Credence is lent the view that habit actions are simple final responses by the fact that the precurrent attention reaction is functionally very simple. Instead of being a definite autonomous reaction system as is the case in volitional or voluntary

---

[2] Concerning this point and the discussion of the behavior segment and its partial phases, see Kantor, A Tentative Analysis of the Primary Data of Psychology, Jour. of Philos., 1921, 18, 253 ff.

actions, in habits the reaction system is much abbreviated morphologically and slighter functionally. All this is to be expected in a behavior segment in which the whole response factor is very definitely integrated with the stimulating conditions. Functionally speaking the attention factor in a habit segment operates, in the overt reactions at least, merely to bring the person in contact with a new stimulus mainly by a shift in postural attitude. In the larger types of habit action the attention factor is of a more complex sort but always simpler than in a correspondingly complex behavior segment of another type of psychological activity. But however limited the attention reaction may be in habits it is undeniably present and adds to the complexity of the total behavior segment.

What is true of the attention precurrent reaction is equally true of the perceptual or ideational precurrent reaction systems. They also are very intimately integrated with the attention factor and the final reaction as well as with the stimulus object or situation. Because of this integration of response factors with the stimulus any very deliberate cognitive action appears unessential, a fact which has lent support to the view we have mentioned, concerning the absence of mental factors in habit responses. Patently, the presence of the perceptual and ideational reaction systems, howsoever fused they may be with the other members of the response pattern, adds to the intricacy of the habit situation precisely as the inclusion of the attention factors.

To the complexity of habit behavior segments there is in fact no end. Possibly it is in part at least owing to this intricacy of habit responses that psychological literature is so replete with discussions concerning subconscious phenomena. For it is indubitable that habit integrations among other psychological phenomena, make it possible for us to do so many and such different actions without any apparent interest in or awareness of those actions at the moment. Is it not such activities as these that we characterize as subconscious phenomena? Clearly such phenomena are no more mysterious than the fact that the person who is in constant or frequent contact with particular complex stimuli can build up an elaborate equipment of habit reactions, which becoming organized as part of his personality, can later operate without knowledge or direction on the part of the person.

Possibly we can make the most striking observations of the operation of a person's complex habit responses when his behavior is so exaggerated as to amount almost to dissociation. Then the operation of habit reactions seems truly remarkable upon the surface. And so it was in connection with abnormal individuals that the doctrine of the subconscious was primarily developed and most extensively fostered. An added feature that made possible the interpretation of complex habit responses as some mysterious "subconscious" was that such responses need not necessarily be cognitively acquired. That is to say, we may organize these complex habits without in the least knowing at the time that such an acquisitional process is going on.

Not our purpose is it now to attempt to establish an identical relationship between complex habit responses and what may legitimately be called subconscious action, for in the first place, such a direct and complete identification does not in fact exist, since subconscious behavior involves much more than habits and in the second place, we have another aim. We are rather interested in pointing out by our references to the so-called subconscious and unconscious activities the enormous complexity attained by the habit behavior segments, and may we mention again that the inevitable implication of this complexity is that habit responses must be looked upon both as precurrent and as final responses.

IV. A COMPARATIVE ANALYSIS OF A HABIT BEHAVIOR SEGMENT

No better analysis can be made of a generalized habit behavior segment than by comparing it with a reflex segment, since the simple habits of a manual sort, consisting as they do of simple automatized responses greatly resemble the reflexes.

Outstanding as a difference between reflexes and habits is the relative prominence of the response and the stimuli factors in the organization and operation of the behavior segments. In the case of reflexes the action depends almost entirely for its formation and operation upon the biological character of the person. In other words, reflexes are very intimately related to the individual's organic structure and functions. The emphasis is on the organism's adaptational need, but these needs are more or less independent of the specific surrounding conditions. As a corollary to this fact of the dependence of reflexes upon organic conditions we find that the reflex segments on the response side consist of only single reaction systems and never patterns of response.

Now in contrast with reflex segments, habit acts are developed more prominently as adjustments to definite external circumstances and in consequence the responses are more conditioned in their genesis by the needs and exigencies of the stimulating surroundings. When we assert that habit responses depend more definitely upon external conditions we mean to confine our statement to the narrow limits of the immediate stimulus-response situation. For it is clear that the auspices of any behavior development must include many elements which are not specifically stimulus conditions, such as organic or more remote economic conditions, etc., all of which intimately concern the individual irrespective of what his surroundings may be. To take a concrete example, the acquisition of typewriting skill responses may be originally and primarily induced by economic pressure and certainly not by the machine, but note that the specific reaction systems are intimately determined by and bound up with the copy and machine stimuli. In plainer words, habit behavior depends more upon the stimuli conditions than upon the structure of the person, although the latter element must always be an essential factor in the formation and operation of all behavior. This fact, by the way, is only slightly less true of thought habits than of comparatively simple skill reactions.

But just because habit responses depend more for their development and operation upon stimulating situations they are more complex and involve more than one reaction system. And these many reaction systems are naturally precurrent attention and cognition reactions.

In point of fact and in complete consonance with our analysis in the preceding section we may locate the salient features of habit responses in the precurrent reaction systems which we may call the cognitive factors. According to our view the sole cognitive fact in a reflex lies in the differential character of the simple reaction system constituting the entire response phase of a reflex behavior segment. Now this of course is the simplest type of cognitive phenomenon in the entire domain of psychological facts. Now in the case of habits a much more complicated cognitive situation is present; here the cognitive factor is represented by the operation of a definitely morphologically autonomous reaction system, the function of which appears to be to mediate between some specific stimulus and some particular final reaction. This cognitive precurrent reaction system may be merely a perceptual reaction or it may be an implicit meaning reaction. The former kind would be found in the simpler habit segments while the latter may be the precurrent components of the more complex habits.

Our hypothesis that habit acts are primarily integrations of responses with stimuli suggests that the precurrent cognitive reaction systems of the habit segment are perceptions or meanings directed only toward the stimulating objects or circumstances which do not anticipate the final action which follows or the results or consequence of the response, although of course the precurrent reaction is always in some way connected with a final response. Let us observe that the question whether there is or is not a precurrent reaction system in the behavior segment and the problem as to whether the precurrent responses refer to the stimulus or the act or both, give us the varying degrees of cognition. When the organism has the precurrent reaction system integrated very closely with the stimulus, as is the case in habit, then we have a comparatively simple cognition involved. What we have here is a process of double association or integration; on the one hand, there is the integration of the precurrent reaction with the stimulus and on the other just as definite an integration of the same precurrent reaction with the final reaction. For instance, the stimulus for the typist is his copy, his perception of the words before him the precurrent reaction, which directed only toward the stimulus is, however, intimately integrated with the final reaction, or the striking of the typewriter key in our illustration.

In behavior which is more complex than habit reactions the integration of precurrent reaction and stimulus is not so binding and the connection between precurrent and final may be such that the person may also perceive the final act; then the precurrent act may be called preparatory. In such a case the activity is described as containing or involving much more or higher awareness. When the precurrent reactions are relatively free in the behavior segment and this would almost inevitably mean that it is an ideational process, free, that is in the sense that the person can anticipate the final act and look forward to it and modify it, then we have what is almost the complete antithesis to a habit response. This would be true even if there be no control or modification of the final act but merely its anticipation or possibly a silent self-remark about it, a questioning whether it should be done or how. This complex type of behavior appears all the more antithetical to habits when we observe that in many cases of habit segments the precurrent or preparatory reaction may be a single overt response;[3] for in such a case we will find that the segment includes the least awareness, excepting such segments which contain only a single reaction system, that is to say, no precurrent or preparatory act. In a genuine sense, therefore, habit responses are actions standing midway between the reflex type of action and the various orders of volitional response.

V. THE STIMULI IN HABIT REACTIONS

Because habits cover such a large range of our behavior equipment and because they are specific integrations of responses with stimuli we will find that as a record of fact the stimuli phases include a large block of our surrounding objects and conditions. Among these multitudinous stimuli we must include persons, things of all sorts, as well as actions and institutions, besides physical, social and cultural conditions of every description.

---

[3] For a brief account of the various types of meaning responses, see Kantor, An Objective Interpretation of Meanings, Am. Jour. of Psychol., 1921, 32, 321.

Naturally, habit responses to physical things constitute a large part of our simpler automatized responses and there is a definite correlation between the increasing complexity of such physical objects and the complexity of the habit reactions that are integrated with them. For instance, the habit responses built up in contact with an automobile or more complex mechanical object are indefinitely more complicated than the habits organized through contact with simpler physical things. And we acquire through various combinations of stimuli our complex skill habits which we will later call achievements and accomplishments. To play the piano we must integrate responses of musical information and piano key manipulations with the music and piano stimuli. Similarly, in typewriting the integration process involves the organization of movements responsive both to the machine and to the copy.

Exceedingly prominent as stimuli for habit responses are actions of the person himself and of others. As such the actions of the individual may be divided into two classes; the first being the organic reflexes of various sorts which directly and exclusively stimulate various simple autonomic habit responses as well as serve in the capacity of auxiliary stimuli to the person's acquisition of complex habits of thought and feeling. Illustrative of the simple habit reactions integrated with organic actions are the mannerisms of walking, facial gesturing, bodily carriage, mode of hand shaking, and speech mannerisms. Among the individual's more complex habit responses those partially integrated with organic actions are such as traits of thought and feeling, particularly characterizing one's outlook upon life, as pessimistic, optimistic, melancholy, etc. In the second class of actions stimulating habit responses we may place all the other responses, overt muscular acts, speech responses or implicit behavior, any one of which may be intimately connected with some other action as its response. Doubtless the best examples of the operation of responses as stimuli to habits will be found in the various combinations of our language habit reactions.

Besides simple and complex objects of various sorts, events and conditions induce us to acquire many habit acts which on the whole are not only more complex than the habits stimulated by objects but are also somewhat more indefinite and general in organization. Consider the difference between an automatized manual act and a response of verbal or general gesture of social politeness.

Complex events and institutions such as economic conditions and political happenings constitute a common variety of habit stimuli and of course the habit acts integrated with such stimuli may be expected to be very intricate. Here our habit reactions partake a good deal of social custom, that is acts determined by social usage and convention. Because the stimuli in the present class are more indefinite in their description and appear extremely vague we may be pardoned the impression that at least some habits are general forms of reaction and not specific response types. The more we consider the specific fact of integration as the principle of habit behavior, however, the less plausible appears this surface impression concerning the generality of habits.

Very incomplete would be our attempt to mention some of the outstanding forms of our habit stimuli if we left out of our enumeration the personal ideals and other individualistic institutions which are integrated with definite complex social, economic and aesthetic habit responses. Possibly the least ambiguous illustrations of such stimuli can be found in the domain of our habitual moral and aesthetic conduct, which if examined carefully we find to be definitely integrated with personal stimuli, whether operating alone or in conjunction with other stimuli forms.

The intricate organization found among our stimuli situations offers us considerable insight into the complexity of some of our habit responses. To take for instance the various physical and social objects and conditions affecting such a pervasive and common action as our conduct at the dinner table. The specific phases of our dining behavior are connected not only with the food, service, and other persons dining, but also with social, moral and economic customs and conventions in confusing array. Manifestly is the situation magnified and intensified when we consider those stimuli integrated with still more complex actions than eating.

Besides the connection of habits with many stimuli objects and conditions, habit responses are also very closely linked up with the settings of stimuli. Particularly noticeable is this fact in connection with social habit responses. In such activities the person's actions, though operating very directly through the influence of their integrated stimuli, do not render him insensitive to change in the specific stimuli settings among which the reactions take place. By the stimuli settings we mean to refer of course to objects, persons, moral, social and esthetic circumstances; in fact, everything that is or can be a stimulus can also be the setting or background for a stimulus. When we consider the infinite possibilities of combination of stimuli and settings we achieve much information concerning the correlational facts which may or may not be considered as causes for the enormously intricate habitual equipment of a highly organized personality.

VI. TYPES OF HABIT RESPONSES

If habit behavior is primarily characterized by the fact that it consists of responses very closely integrated with stimuli it follows then that because of the great variety of stimuli with which we are in contact the number of different classes of habit reactions will be very large. As opposed to the psychological tradition to which we have referred, namely, that habit reactions consist only of the comparatively simple overt acts, exemplified by swimming, walking or typewriting, we propose the hypothesis that our habit reactions comprise acts of the most diverse classes and individual description, acts which are stimulated by the most divergent forms of objects and conditions. An investigation of our behavior equipment reveals immediately that we have habits of feeling and of thought as well as of motor skill. Furthermore, be it observed that the terms motor skill, thought and feeling are conventional rubrics based upon the traditional conception of the tripartite division of what was presumed to be the subject matter of psychology, namely, consciousness. What we are eager to point out here, therefore, is that a valid appreciation of the actual types and descriptions of our habit equipment must be based upon an acutal study of our responses. This means to say that to seek for the concrete reactions in our behavior equipment representing close and specific integration of stimuli and responses would reveal a large catalogue of habit types. Indeed it is to a large extent true that our complex habit responses constitute a good portion of the behavior equipment of our mature personalities.

Unfortunately for the student who desires to classify habit responses, the fact just mentioned, namely, that habits are pervasive and common forms of our behavior equipment, and that they are specific forms of adaptational adjustments, provides almost insurmountable difficulties. How can we bring order into such a host of divergent behavior data? That such an arrangement can only be accomplished by ulitizing a series of different criteria is almost obvious, and so whatever organization is made of the habit facts will have to be made at the expense of a rigid logical scheme. As a matter of fact, our classification will be made on the basis partly of the stimulating situation and partly on the morphologic organization of the responses, and partly upon the place the responses take in the behavior equipment of the individual, although, because of an obvious expediency, the most striking and comprehensive basis of organization will be of course the stimuli situations forming parts of the habit behavior segments. Again, we must note that the names we employ for the classification of our habit responses should not be taken as in any sense exclusively belonging to the habit reactions. That is to say, when we mention sentiment as an example of feeling habit we must immediately point out that the name sentiment does not refer exclusively to habit actions but may be just as appropriately applied to numerous other forms of responses. Especially must we guard against the uncritical acceptance of a popular conventional term as a substitute for an analytical psychological category.

But if we attempt to classify habit responses upon the stimulus basis we must almost inevitably duplicate the discussion of the preceding section, inevitably because of the extreme integration of stimuli and responses in habit segments and because the enumeration and description of habit responses can frequently be made only in terms of the stimuli auspices under which they occur. However unsatisfactory our classifactory procedure may be we have no option but to proceed in this manner and for our present purposes we may adopt a three fold classification of stimuli, dividing them into our (1) physical surroundings, (2) social surroundings and (3) personal stimuli, namely, personally formulated ideals and other institutions. Such a division must appear extremely inadequate and arbitrary, but since in the present section we are primarily interested in the responses such a classification will appeal to us only and precisely in the measure in which it is found useful for our immediate purposes.

1. Habits integrated with physical or natural stimuli

Here we may illustrate our point with a series of sample acts as follows.

a. Among the simplest habit responses in this class are the so-called manual acts exclusively denominated habit by the older psychologists. The examples usually given are the swimming acts, telegraphy, dancing reactions, typewriting, walking, writing, and other overt formal responses of a practically mechanical sort. In general we may add to this classification numerous other abilities of the person consisting of specific reaction systems, which, being so integrated with a particular physical stimulus, operate immediately when that stimulus appears. Here we may name the components of such reactions as cooking, and craftsmanship of various sorts.

b. Prominent among habit responses integrated with physical or natural stimuli are the aversions and preferences which give so marked a character to our personality. We might mention here the aversions toward the objects or persons of certain qualtities, sizes, and shapes toward animals of various morphological descriptions or harmfulness, and the preferences we acquire toward objects, persons and conditions. Also, we might include here various likes and dislikes which of course are generally more complex responses to things and persons than mere preferences.

From the morphological standpoint the responses under this division may be considered as involving more the feeling qualities of tastes than the effective attributes of skill responses.

c. Another series of habit responses integrated with physical and natural stimuli we may refer to as capacities of many sorts, adding, multiplying, distance judging, and accomplishments such as reactions of painting, drawing, and the manipulation of musical instruments. Our criterion for differentiating these behavior segments from more complex ones in class (*a*) is the greater indefiniteness of the habits now under discussion, the greater difficulty in formulating a morphological description of them and the generally more important function they perform in the daily activities of the person.

d. Probably the most striking if not the most familiar of our behavior to physical and natural stimuli are our various attitudes toward and beliefs about them. More or less intangible and indefinite are the attitudes towards the relationships of things themselves. Such habits of thought and opinion may very frequently be most appropriately named superstitions. But this does not exclude the presence in the individual's behavior equipment of numerous other attitudinal types. The main point here is that the stimuli mentioned are the immediate incentives for the arousal of informational, economic, social and aesthetic responses, responses which in many cases precede or are accompanied by overt acts. When this happens the mechanism appears to be this, namely that the habit responses, or the habit responses coupled with their appropriate stimuli, serve together as the stimuli for the accompanying or correlated overt responses. For some individuals the appearance of lightning is the stimulus for some superstitious notion which in turn becomes the stimulus for the performance of some rite if it be only the seeking of seclusion and shelter.

2. Habits integrated with social and intellectual stimuli

a. Many of our habit responses to social stimuli are of the same morphological character as those responsive to physical stimuli.

We need only suggest some concrete examples. When we speak of an individual as having industrious habits we must plainly include in such a statement direct overt acts. Similarly, to speak of a careful speaker means to pass judgment upon the person's direct overt language responses. Why it is that we have identical habit responses integrated with both physical and social stimuli is transparent when we recall that the same physical objects can serve as physical and social stimuli.

b. While it is obviously true that overt habit responses of the sort usually described as motor reactions may be connected with social as well as with physical stimuli, still it is clear that for the most part habit responses to social stimuli will be of a less direct and overt type. Many types of social habit responses there are which because of their unfocused character and extension in time are usually thought of not as adaptation acts but as qualities of the person. To illustrate, we believe that an act of politeness involves a pattern of habit reaction in precisely the same sense as a typewriting act but because of the general character of the social situation we usually fail to note the unitary character of the response pattern. Of a certainty when we locate the politeness habit in the specific act of tipping the hat or in bowing we have a case of social habit which is in no wise different from the overt habit response to physical stimuli, but we would indeed find it unprofitable so to restrict the politeness behavior segment. We conclude, then, that the classification of social habit responses must comprise less tangible responses of a definitely adaptive sort than those we find in the overt reactions. Now although we cannot give specific detailed account of the social habit responses we may in lieu of such definite description refer to some of the categories which our language has developed for suggestions concerning some of the social habit reactions, and perhaps also for some insight into the nature of the latter. Let us specify as social habit behavior social mannerisms, politeness, sincerity, suavity, encouraging, deprecatory, appreciatory, dissenting, dissembling, mercenary, artistic, efficient, exact, conforming reactions, etc. Without attempting to specify precise stimuli for each case, the categories of which would be of infinite length, we might point out that a differentiation of the members of this class of habits could be made by considering that the stimuli include things, persons, institutions and conditions of every variety. Efficiency and industry habits would be responses to physical-social stimuli; mercenary and exact habits would probably correlate with social conditions or stimuli, while sincerity and suavity responses correspond to persons as stimuli.

c. Both interesting and important are the numerous habit responses, which because of their particular morphologic organization, we may call feeling actions. In this class we may place sentiments, faith, reverence, awe, prayer and mystic exaltation reactions to what we might call religious stimuli, conditions and situations. Also, among these feeling habits we may place love reactions toward persons, and appreciative responses to art objects and aesthetic works of nature. Easily recognized are the feeling habits of depression and incipient melancholia which we acquire as responses to social stimuli of various sorts and to some sorts of physical stimuli also. Faith habits need not be connected merely with supernatural things or conditions represented by words or other institutions, but we develop faith reactions to our capacities and success in life, or acquire faith in other persons and in social institutions. When we consider such habit responses as sentiments we are more than ever convinced of the large series of specific stimulating situations to which we respond with complex feeling habits; for we make sentiment responses to all kinds of political, moral, economic, religious and aesthetic situations. It will not be superfluous to mention again that our criterion in this class of habit responses is mainly morphological, and to be specific, we might propose the hypothesis that these responses involve large elements of glandular, autonomic—nervous and affective factors irrespective of the stimuli with which they are connected.

d. To another series of complex social reactions we may give the name intellectual habits. To the intellectual surroundings about us we acquire direct and immediate modes of response. Morphologically all the members of this series when considered as a class are more alike than unlike, while the members of any specific one of the types differ more from the members of non-intellectual habit series than from any specific type of the intellectual series. But this fact of morphological likeness between the members of the intellectual habit series does not extend at all to their functional character for in their operation the different members are unique. To illustrate this difference we propose to call these habit reactions, attitudes, opinions, beliefs, convictions and intuitions.

1. By intellectual attitudes we mean the fairly vague cultural responses to intellectual stimuli. Workingmen respond habitually to problems affecting them in a manner that we might call a worker's standpoint. Similarly the capitalist is habituated to think in terms of the increase and conservation of capital and industrial control. Habits are very directly connected with the group auspices under which they are formed. Thus nationality, social stratum, profession, clubs, churches and in fact every group connection modifies the cultural attitudes, no matter what the individual starts with. Naturally there are many factors which condition this modification of intellectual attitudes, among which are length of contact with the present person or group, besides stability and authority of the stimuli in the situation.

2. Opinions as intellectual habits are specific intellectual attitudes concerning particular facts and conditions surrounding the individual; they are the permanent records of the results achieved from the specific problems a person has faced and are genuine products of the interaction of an individual with his informational surroundings.

3. Intuitions are subtle modes of intellectual responses which are developed within the boundaries of a given field. Individuals appear to have capacity to perform certain intellectual functions with an ease, rapidity, and correctness which on the part of others requires long and laborious calculation and reasoning. In the popular mind women are especially gifted with this power, but this conclusion, as all those of similar origin, is unwarranted by fact. Intuition is an every day capacity possessed by all individuals in a certain degree. Women who have had family

responsibilities for a considerable time come to discern with acuteness, and subtlety the conditions affecting the home group. They habituate themselves so efficiently to conditions influencing the family and its interests that they become marvelously adept in observing untoward changes in it, and respond immediately in the way of correcting these undesirable conditions. The same situation prevails in the case of the experienced business man who seems to solve his problems without any reasoning. Here the fact is the same as in the preceding case; long familiarity with similar conditions engenders a capacity to short-cut the solution; the usual trial and error factors are gradually eliminated. The individual concerned has learned precisely how and where to direct his attention in the particular case, the facts in the situation need not be elicited; they appear directly upon the surface. Intuition then is a habit of solving problems of all sorts no matter what they are specifically, whether practical problems of every day life or technical problems of commerce, industry, law or what not. Intuitive modes of intellectual activity are especially common in mathematical studies and the consequence of this sort of integration we have been describing is that the mathematician solves complex problems by ostensibly merely glancing at them.

4. Belief habits are very similar to opinions but a difference can be located in the definiteness with which the person is in contact with the informational stimuli. Belief habits are actions integrated with stimuli facts to which the individual reacts in such a way that the facts in question are inadequately known or appreciated by the acting individual. Possibly it is true also that belief habits are the connecting links between the intellectual and the feeling habits.

5. Convictions are definite modes of intellectual response towards somewhat less specific informational stimuli and conditions and are more deeply rooted in the behavior equipment of the individual than are opinions. That is to say, a greater element of social convention enters into the process of building up convictions and consequently they are more obviously a part of our intellectual equipment and refer to more prevalent and stable facts and conditions in our cultural milieu. Also, convictions

may be said to be characterized by a lesser appreciation on the part of the individual as to the conditions which led up to their acquisition than is the case with opinions.

Other intellectual habit responses might be isolated and in each case we would find a typical form of response coupled very intimately with some sort of social or intellectual stimulus situation. We need only mention impressions of all sorts, superstitions, prejudices, and conventional views, to make clear that the list of intellectual habits is a longer one than we have intimated. Consider the infinite possibilities for the integration of habit responses which are found in and suggested by the various cultural and social institutions about us. To make a catalogue of our habit equipment we would have to point out the responses induced in us by all our surroundings, economic, social, national, religious, political and intellectual institutions.

3. Habits integrated with personal stimuli

Since personal stimuli are merely social institutions of various sorts deliberately modified or accepted by the individual we shall expect that the habit reactions to such stimuli will be more refined and individual responses of the same general order as we have just discussed. One feature above all stands out and characterizes the habits integrated with personal stimuli and this we may define as a peculiar intimacy of response in any particular case and a definite coloring by the peculiar behavior equipment of the person.

Among the prominent habit reactions in this class we may mention ideals of all sorts, moral, social, scientific, aesthetic, etc., ambitions, strivings, criticisms, and other familiar adjustments to personal stimuli. We should not expect of course to find any degree of commonalty between the personal habit equipment of different individuals.

From our study it should seem strikingly clear that such a catalogue of habit traits or characteristics of behavior can only be very fragmentary and schematic. Any enumeration that is made must very obviously be merely a sample of any person's equipment. In the first place, it is impossible thus to catalogue all the habits that are acquired by various individuals since the list would be of appalling length. And in the second place, no significant catalogue can be made unless it is taken from the equipment of specific individuals. Above all we must observe that the names we apply to the habit reactions are not only not absolute terms representing a single form of habit, but as we have already indicated they are not exclusively the names of habit responses. They may just as easily be applied to acts which do not answer to the particular integration characteristics which we have suggested as the particular marks of habit behavior segments.

VII. HOW HABIT RESPONSES ARE ACQUIRED

To inquire into the mechanism of the acquisition of habit responses means to investigate the conditions under which they are built up. Immediately we observe that two sets of such conditions must be attended to, since habit acts as we have repeatedly stated have two salient features, namely the stimuli situations and their corresponding responses. Accordingly we find in this fact a natural division of our inquiry.

a. Response conditions

Under this rubric we may discuss the conditions of habit formation which have to do mainly with the response factors of habit behavior. And first we may observe that we can point out two main sources for the development of the habit response systems.

1. The development of new reaction systems. The organism has at any period in its career a definite equipment of response systems which have been developed upon a basis of previously acquired ones. Now the newer organization, or perhaps we should say, in some cases at least, the reorganization of response systems, is a process of integrating a larger action system by the stimulation of some given stimulus object or condition. In the final analysis these habit response acquisitions go back to what we may call basic behavior, that is to say, the first and original

adaptive responses which in turn are integrated from simple responses which may not improperly be called organic responses and original action properties of the individual.

2. Another and equally fruitful way of developing habit response systems is by conditioning reactions we already possess. This process is very similar if not identical with that of conditioning reflexes and exemplifies admirably the essential feature of habit behavior, namely the integration of responses with stimuli. Through this second mode of habit formation are built up the large majority of social habit responses.

b. Stimuli conditions

In some cases the stimuli may correctly be said to be responsible for the cultivation or establishment of the habit responses with which they are connected. Among the stimuli conditioning habit reactions are the following.

1. Natural objects and conditions. Because we have around us physical objects, persons of particular sorts and physical conditions we integrate with them specific modes of behavior. To illustrate, we might deem it almost inevitable that we must build up swimming or rowing habits when we live near a river or other body of water and especially if we must frequently cross the stream. Essentially we must consider habit responses as adaptive functions and when the natural surroundings dictate, the appropriate responses will be acquired. The same may be said about the acquisition of language habit reactions. Language conditions necessitate the building up of particular sorts of verbal and speech reactions.

2. A common and well known stimulus condition for the acquisition of habit responses are the functioning of the person's own organic reflexes. With such action stimuli are integrated the habit responses popularly called drug and drink habits. In these phenomena we have a definitely circular process in that we acquire the stimulus as a habit response. The ordinary mechanism is somewhat as follows. Through contact with liquors, drugs and other objects we develop organic reflexes of all varieties which

may be considered as organized into definite habit responses. Because these responses are organic reflexes they are easily aroused to action. But in the course of their organization these organic habits have become integrated with various overt manual and social acts which have become in a genuine way responses to the organic habits as stimuli; so that now when the organic reactions are functioning they serve as stimuli to call out the other actions. It is these latter which we are calling the habits in this case, although the phases of drug habits which we call the coercive and distressing features may appear as the typical features in the habit situation. These types of habit actions are peculiar among all the habits of our behavior equipment in the fact that only in them are the stimuli in any way increased or modified.

3. For the formation of complex social habit responses a definite series of human conditions are urgently operative. We need mention only the economic, social and moral pressures exerted upon us by our surrounding conditions. Frequently such conditions are direct adjustmental stimuli for the acquisition of habit responses, but in many other cases these economic, social and educational conditions serve merely as auxiliary stimuli. Consider the particular thought habits of a person who is definitely an adherent of a certain professional or other vocational group. How differently the minister appreciates social dicta and how much more sensitive he is than the gambler or other person who profits more by various unconformities to group pronouncements than by the support and perpetuation of them. Also, within a fairly restricted circle we can observe how much more stable and definite are scientific facts and formulations to the teacher of them or the practitioner who uses them than to the discoverer and the investigator. And how much more easily the discoverer is induced to question and relinquish what are considered facts than the physician or teacher.

4. Meriting special discussion are the social institutions among which we all live and which almost inevitably and imperiously compel us to build up all descriptions of social habits. By social institutions are meant customs, conventions, organizations, and

actions which are common stimuli for the behavior of the various individuals forming the groups among which we carry on our behavior. Many if not most of what are called social traits consist of the social habits acquired through contact with institutional stimuli.

5. A very important form of habit responses are those which we are practically forced to acquire as responses to personal stimuli, prominent among which are the attitudes, thoughts and beliefs of other persons directed toward the high estimation and the furtherance of our interests and advantages, and therefore we are forced to acquire habits, actions and thoughts for the preservation and progression of those interests. How many such habits the person actually acquires it is almost impossible to estimate, but that the list is an enormous one it is not difficult to convince ourselves.

In this connection a very interesting and important problem arises with respect to the influence our intentions have upon the acquisition of our habit behavior equipment. In the simple responses to natural objects it is clear that the person's intentions are as far removed from the acquisitional situations as can be. But in the acquisition of our complex social habit responses a far different condition prevails. In the more complex situations we may be very definitely and very largely conditioned by our choice and preference. We intentionally build up habit responses of all sorts to suit our own fancy and purposes both by our interest in the results to be obtained from the possession of the habit and our interest in the action itself. When the intention of the individual is considered in connection with various stimulating circumstances we may properly speak of the motivation operative in habit formation. For by motivation we mean the process of weighing and evaluating the various objects and conditions stimulating us to action. When we have a problem of motivation in connection with habit formation we may properly say then that we are considering both the response and stimuli phases of the habit situation. Typical of intentional habit reaction acquisitions are the mannerisms, customs and accomplishments we build up in order to attain to a certain level of society or to gain an advantage over other persons or groups.

c. *Combination stimuli and response conditions*

A great many of our habit responses are acquired through the influence of both stimuli and response conditions operating at once, but contrary to our other two cases in which either the stimuli or response conditions were more predominant in this case the two conditions are equally prominent. Specifically these twofold influences upon our processes of habit formation may be considered as identical with the general conditions of association, commonly referred to as frequency and recency of contact, the condition of the organism at the time, etc.

VIII. MODIFICATION OF ACTION THROUGH THE OPERATION OF HABITS

That individuals acquire many advantages through the acquisition of habits is a familiar fact of current psychology, and the writer is encouraged to believe that the integration hypothesis of habits serves better to account for this fact of modification than any statement that has yet been proposed. Let us recall briefly what are these advantages accrued from habits. It has been asserted, and quite correctly too, that habits make for specificity, ease, accuracy and speed of action. Do not all of these advantages follow very clearly from the fact of integration? Furthermore, because habit responses are so definitely and inseparably connected with particular stimuli we can readily see how the presence of many habits in the behavior equipment of the person would mean that his production of any given objects per unit of time would be greatly increased and his work accomplished with a miminum of fatigue.

Now all of the above advantages refer to habit actions which we may call fairly simple overt responses but since our range of habits is not exclusively confined to such comparatively simple responses the catalogue of advantages would apply equally to other types of habits. Especially would this hold true for acts involved in the solution of simpler mathematical problems, the formation of judgments in various fields of work, and other forms of action. Obviously, not all the advantages mentioned apply to all specific types of habit action and on the other hand, other advantages to the organism than we have mentioned might be elicited.

Turning now to the more complex forms of habit responses we might say of them that they adapt the person in his larger behavior setting, and by the latter we mean the social situations in which the person finds himself. Our point is that the more complex habit actions such as talents, information and technological skill may operate to give the person social and economic advantages or merely to increase his standing in the estimation and graces of his contemporaries. In many cases the advantages to the person may be so lacking in definite adaptational value that we can not say more than that the person is a better individual than he would have been without the particular habit acquisitions in question. In the latter case, we may more properly speak of the superiorities accruing to the personality rather than any advantages of adaptation either social or organic.

It remains now merely to point out that while any habit behavior segment when considered by itself operates more smoothly and more directly than a non-integrated segment this does not necessarily mean that the habit act as a whole will redound to the advantage of the person. Very frequently it is the case that habit actions place the individual at a great disadvantage. Strikingly appears this point when we consider such habit responses as tics, choreic movements and the various mannerisms that are disapproved of socially.

IX. SUMMARY

Habit responses as unique action components of the person's behavior equipment we find to be definite responses of the individual to specific stimuli—objects and events. The principle point then about habits is the fact of the close integration of the stimulus and the response. If this view be correct we can readily appreciate why it is that habits appear to be, on the one hand, general capacities, while on the other, they seem to be specific responses; that is to say, the term habit may be considered as a generic symbol for responses of various morphological types.

But after all, this integrative character of habits accounts for the fact that each distinct habit connection comprises some specific form of response and some particular stimulus or condition.

Since the process of integration takes place at all levels of our action there appears no warrant to limit habits to simple overt responses. Rather, we might say that no matter what the particular reaction is it may be inseparably connected with some particular stimulus. Accordingly, as we have seen, the list of habits may include social responses, intellectual and feeling activities as well as simple overt reactions. Emphatically, this does not mean that the term habit symbolizes all the reactions acquired by the individual.

Again, in the conception of habits as intrinsically integration of responses with stimuli we find some valuable suggestions for the approach to the problem of habit formation. As long as psychologists attempted to find the factors for habit formation exclusively in the physiological organism no definite progress could be made in the solution of this problem. When habits are considered, however, as integrations of responses and stimuli the careful study of the stimulating auspices of the individual must yield significant and serviceable information concerning how habits are formed or acquired and how they operate later. Upon such a basis may we not entirely dispense with the peculiar idea which is all too prevalent that we can learn habits with the cortex and later perform the reactions with the so-called lower centers?

In this integration conception of habits we also find suggestions as to what the differences are between habits and other forms of behavior so far as attention and cognition are concerned. The matter appears to be as follows. Whereas in various complex actions the attention and cognition reaction systems are autonomous acts preceding the final response which gives the name to the behavior segment, in the case of habits the whole action phase of the segment is so closely integrated with the stimulous situation that the preceding attention and cognition reactions are muchly syncopated and serve no very elaborate function. Not the least significant value of the integration conception at this point is the intimation of what psychologists actually mean by the increased presence or absence of conscious factors in behavior.

THE SENSORIAL BASIS OF MUSIC APPRECIATION

OTTO ORTMANN

From the Psychological Laboratory of the Peabody Conservatory of Music

The sensorial basis of the appreciation of music forms a logical and at the same time adequate and necessary basis for a psychology of musical enjoyment. It is logical, because it treats of the beginning of such a psychology, fitting it into its place in the scheme of general psychology; adequate, because it includes, without exception, all the raw material which later on is molded into many wonderful and intricate reactions. It is necessary because, without it, any pyschology soon becomes lost in the labyrinthine complexities of what is generally understood by the expression, "musical enjoyment."

An analysis of the sensorial basis of musical enjoyment does not answer all of the many questions that are thrust upon the investigator of this interesting field at every point and from every angle. But it does furnish us with the basic facts from which these answers must ultimately be derived. It is true, that the path leading from the simple tone-sensation to the enormously complex reaction, experienced, let us say, when the Philadelphia Orchestra under Stokowski plays Wagner, is neither direct nor single. Yet, whatever its meanderings and ramifications, it is a psychological continuum, unbroken by any of the popularly postulated gulfs of mystery. If the complex reactions to music cannot yet be explained, this failure is not the result of the entrance, at some point or another, of some super-psychological forces, but the result of our inability clearly to trace, throughout its length, the unbroken chain of complex neural response.

Sensation forms the first link in this chain. And an analysis of the attributes of sensation, particularly of those of the auditory field, furnishes a satisfactory starting point.

It is obvious, after even a superficial consideration, that the attributes which suffice for the demands of ordinary life are insufficient to meet the demands of a more thorough analysis. I refer particularly to such a term as "quality," which has long been used with various, in some instances, contradictory meanings. The popular classification of tonal attributes into pitch, intensity, duration, and quality, I shall replace by one which arrays the attributes, as far as this is possible, according to their psychological fundamentality and simplicity. Thus we get three types of attributes: primary, secondary, and tertiary. Primary attributes are those inherent in the simple sensation, which are unanalysable; secondary, those resulting directly from a combination of the primary attributes; and tertiary, those borrowed or derived from some past experience in the same sensory field or some past or simultaneous experience in some other sensory field. Such a plan separates the sensations resulting from the auditory stimulus itself from those read into it by the complex reaction of consciousness—a distinction of fundamental importance.

There is but one primary attribute of auditory sensation—*extensity.* Extensity has three forms: transtensity (trans = across) or the projection in consciousness of the spatial dimension parallel to the recipient organism; intensity (in = toward), or the projection in consciousness of the spatial dimension at right angles to the recipient organism and protensity (pro = with), or the projection in consciousness of the uni-dimension of time. In the auditory field transtensity produces the sensation of pitch, intensity that of loudness, protensity that of duration. Such a classification accounts for the dimensions of the external world; and since sensation is our immediate and sole initial reaction to this world, the attributes of sensation enumerated form a psychological basis sufficiently comprehensive to include all possible variations in the stimulus. The primacy of extensity as a attribute is proved further when we appeal to other sense departments; for if it be truly a primary attribute it must be present in other sensory fields than audition, since these, like audition, are but reactions to a particular range of stimulation (vibration rate) from the external world. Vision and kinaesthesis, the two best known senses, lend themselves readily to an analysis on the basis of extensity, for in both senses the terms length and breadth, intensity, and duration convey definite meanings. Here, too, intensity is that sensation resulting from extensity in a direction toward the body—a fact which is best illustrated, perhaps, in the field of kinaesthesis. Smell and taste lend themselves far less readily to such a classification. This, however, does not argue against the primacy of extensity, since we know so little analytically about the olfactory and gustatory senses that it is inadvisable to cite them either in support of or in opposition to a theory. The treatment of pitch as extensity, or as it is here called, transtensity, is in line with recent physiological theory (1, 2, 3, 4, 5). Intensity as extensity of another dimension is a far less frequently met concept but one which also may be brought into agreement with recent theory (6, 7, 8).

The primacy of protensity is obvious. And the primacy of each of the three forms of extensity is proved by the fact that the elimination of any one of the three attributes destroys the entire sensation. What we consider intensity, is, in reality, an extensity in a direction toward the recipient organism, as the prefix "in" suggests. The interposition of the recipient organ, however, prevents the extensity from being manifest as such. Thus if the pressure upon an unyielding surface be increased ,we do not get motion in the direction of the pressure, but we do get the result of it, namely, an increase of force or intensity, and if the interfering surface be removed, we should get the motion. If, now, the recipient surface be a sensitive organ, this increase in force gives rise to that attribute of sensation known as intensity. If, for the sake of illustration, we assume a number of end-organs for a unit of area, intensity is that attribute of sensation resulting from the degree to which any one organ is affected, and transtensity, that attribute resulting from the extent of surface, or the number of end-organs affected, and protensity the length of time the end-organs are affected.

CHARACTERISTICS OF THE PRIMARY SERIES

The essential characteristics of the pitch series are: uni-dimensionality, continuity, and infinitude. These characteristics are present in the external series or dimensions which give rise to the sensations of pitch, and each of them is responsible for a number of immediate judgments of pitch. Thus the one-dimensionality of the series determines the position of any point with respect to all other points; a second point consequently, can bear but one pitch relationship to a first point; of any three points, one must always be between the other two; a point is determined either through its own character, its relation to some other known point, or its relation to the physiological extremes of the series. The continuity of the pitch series demands that any two points may not be separated by a "something else" consisting of either a few or many discrete points, but by a continuous stretch or extent of series, bounded by the given points. The continuity of the series further makes any periodicity, such as that resulting from octave relationship, impossible. We find no such periodicity in the external dimension; hence, since pitch is the psychological projection of that dimension, we cannot admit periodicity as a primary attribute. Points are associated primarily and essentially according to their proximity in the pitch series. Although physiology sets a limit to the pitch series, we have no difficulty in projecting, in imagery, this series beyond these limits. Accordingly no point becomes a real limit, but remains a point along a continuum which extends beyond the point on both sides. The infinitude of the pitch series, however, is limited to central processes and thus falls beyond the scope of the present article. Physiologically, the pitch series is limited at both ends, approximately at twenty and thirty-four hundred vibrations.

The intensity and protensity series have the same fundamental characteristics as the pitch series. Physiology here, too, places limits upon the series. Moreover, as a result of the uni-dimensionality of time or duration, protensity cannot become a series or an "order" at all without introducing periodicity. By keeping intensity and transtensity constant, protensity cannot vary, but becomes the equivalent of the Bergsonian "pure duration," which, for our purposes, may be considered unknowable. Accordingly, periodicity is an inherent attribute of the protensity or duration series. We can keep intensity and protensity constant and pass along the transtensity series, we can keep transtensity and protensity constant and pass along the intensity series; but we cannot, by keeping transtensity and intensity constant, pass over the protensity series. In order for any protensive series or distribution to be at all evident, fluctuations in one or both of the other attributes are necessary; and fluctuations mean periodicity. This inherent periodicity of the protensity series may throw additional light upon the fundamentality of rhythm.

THE FEELING-TONE OF THE PRIMARY ATTRIBUTES

Mere reaction to variations in one or more of the dimensions of the external world, is, in itself, not sufficient to insure the existence of the organism. Some device, enabling the animal to distinguish the harmful from the non-harmful stimuli is needed. This is given in the so-called feeling-tone of sensation. All sensations are either pleasant or unpleasant. In taking this popular view I am well aware of its apparent inadequacy to explain all emotion, particularly the higher emotions; a difficulty which has led to such theories as those of Baldwin, Royce, and Wundt. But the fact that pleasure and pain are the most general, the most simple, and the earliest of psychical manifestations, the existence of which is evident at a time when all other emotions are lacking, points to their biological fundamentality. And just as sensation leads through an unbroken passage to the most complex reaction, so the most complex emotions are based upon the pleasure-pain feeling. Whether or not we accept this view, a defense of which would take us too far afield, is of no consequence in our present problem, which is limited to the physiological and basic aspect. The actual existence of feeling-tone is all that has to be admitted; and a very intense light or sound, or a hot iron brought into contact with the organism leaves no doubt as to the existence of feeling-tone in the sensation. Feeling-tone is nature's device for acquainting the organism with the nature of the stimulus in its effect upon life; without which device maintenance of life becomes impossible. Accordingly, sensations are all pleasant or unpleasant to a greater or a less degree when viewed irrespectively of the complications resulting from higher forms of organic response. The next step in our analysis is a consideration of the distribution of this feeling-tone over the three primary series. For the sake of clearness, each series in this connection will be treated as existing independently of the others; although, as we shall see later, this is not actually the case.

The ear is an organ for reporting vibrations between certain fairly restricted limits. Whatever be the ultimate nature of sensation, electrical or chemical, the ear itself, including the ever so minute structures in the cochlea, is a physiological mechanism; individual, perhaps, in the quantity and quality of its response, but modal in the principle of response. No mechanism responds equally for all points within its range. Such a response would be both mechanically and physiologically impossible, and the impossibility is verified by the data of the psychological laboratory in such tests as, for example, pitch discrimination. These data, moreover, tell us that the best response is near or at the middle of the range of action; a condition which we should logically expect from the nature of the case. At each extreme there exists a sort of mal-adaptation of the end-organ. Mal-adaptation is biologically injurious; hence, physiologically leads to unpleasantness. Accordingly, the most fundamental distribution of feeling-tone is from unpleasantness at each end of the series, through pleasantness near the middle, to unpleasantness at the other extreme. The pleasantness near the middle of a series results from the fact that moderate stimulation of any organ is accompanied by a pleasant feeling-tone, since it furthers the life of the end-organ itself and through the operation of the law of exercise aids the life of the organism as a whole by developing more efficient reaction (9, 10). This, then, is the distribution for the pitch series.

A similar, though somewhat modified distribution exists for the intensity and the protensity series. Very weak tones are less unpleasant than very low tones because very weak stimulations are of no biological consequence to the organism. Very short tones likewise are accompanied by organic indifference. Strong tones are unpleasant because they are directly physiologically injurious to the end-organ; long sustained tones are unpleasant because they fatigue the end-organ by eliminating the necessary periods of recuperation. Sensations near the mid-regions of these series are accompanied by pleasant feeling-tone because of the effect of moderate exercise.

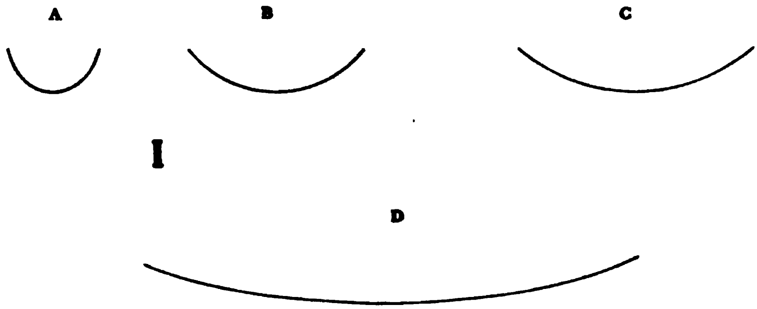
Stripped of all complexity, then, and treated independently of the other series, stimulation from any primary series is accompanied by feeling-tone which is unpleasant at either extreme and pleasant near the middle. If, in actual life, we do not find such a clear-cut distribution, the apparent discrepancy does not disprove the validity of this fundamental distribution, because the variation may be traced to the coexistence of the three series and to the other non-fundamental attributes and reactions. At any rate, if introspective evidence shows such a distribution, we have this to draw upon in formulating a psychology of musical appreciation.

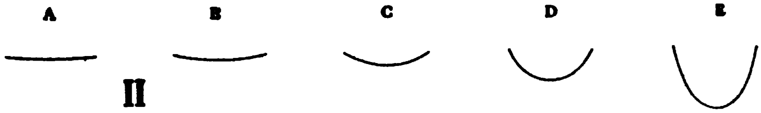
SECONDARY ATTRIBUTES

A sensation, in order for it to be a sensation at all, must possess the three primary attributes of transtensity, intensity, and protensity. The coexistence of the three extensities is a necessary condition for sensation, for the latter is a response to a world of space and time, of which the sensorial projection would be incomplete if any dimension were omitted. This coexistence of the primary attributes produces other attributes which I have termed secondary, because they are derived from the primary attributes. Chief among them is Quality.

Quality is the sensorial complex resulting from the simultaneous presence in consciousness of the three primary attributes. It depends for its particular character upon the relationships of quantity existing among the three extensities. Accordingly, qualities are many and difficult of gradation because any degree of variation in any one or more of the primary series produces a change in quality. Quality, therefore, becomes identical with what I shall call sensation-form. Or, to speak more exactly, if sensation-form be considered physiological in nature, then quality is the psychological reaction to sensation-form. A study of sensation-form now becomes of vital importance, since in it rests the explanation of tonal qualities. The connotation of the word sensation-form is given in the word itself, namely, the actual physiological form of end-organ response.

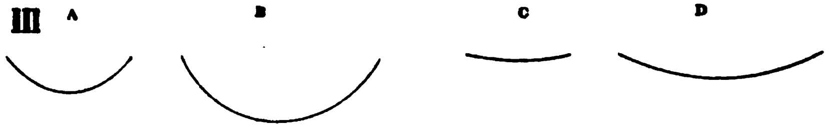
The extensity theory of pitch tells us that tones of low frequency affect a greater stretch of tectorial membrane than tones of higher frequency (1, 2, 3, 4, 5,). Intensity we have conceived as a physiological dimension at right-angles to transtensity. Keeping intensity constant and varying transtensity we may illustrate the principle of sensation-form by the following diagrams which are fairly typical, though enormously distorted sensation-forms: figure 1, *a*, *b*, *c*, *d*. Keeping transtensity constant and varying intensity we get as types: figure 2, *a*, *b*, *c*, *d*, *e*. Types illustrating forms when both intensity and pitch vary are: figure 3, *a*, *b*, *c*, *d*. Duration variation itself is not adapted to diagrammatic representation. It comprises the time required for establishing or "setting" a form and that required for destroying a form, as well as all the transition forms passed through


I

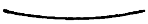

II

in this process. In the diagrams used, pitch is represented by horizontal distances, intensity by vertical distances. A horizontal line joining the ends of the curve of any figure, would indicate the end-organ at complete rest. The recording hair-cells are supposed, in these figures, to extend in a horizontal direction below the lines, so that each form shown would be impressed upon the underlying cells. A curve such as figure 4 represents a low and weak tone; figure 5, a tone of the same pitch but greater intensity; figure 6, a high loud tone; figure 7, a tone of the same pitch but much weaker. The actual dimensions are not to be misconstrued as meaning that these forms actually exist in the ear. The principle of reaction, however, is to be conceived as the same. Sensation-form, as here understood, means simply the total sensorial effect upon the organism of any one uniform sensation, or of any one moment of a variable sensation. It is the unit of reaction resulting from the necessarily simultaneous presence of the three primary attributes and does not, strictly speaking, represent a synthesis, since we can only synthesize what has previously been separately present to consciousness. An illustration from the field of kinaesthesis will make the concept of sensation-form clearer. Assuming that a rough disk be pressed against a surface of the skin, a certain number of end organs will be maximally stimulated, others moderately, and others minimally, as a result of the uneven surface. The total sensorial effect of this uneven, non-uniform stimulation, gives rise to the "sensation-form." Stimulation of exactly the same number of end-organs, but uniform stimulation, or stimula-

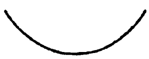
III



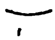
IV



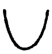
V



VII



VI



tion of a less or greater number, would give rise to different sensation-forms. This we shall see more clearly as we proceed with the analysis of various sensorial qualities.

Now if qualities are the psychological resultants of sensation-forms, what tonal qualities do our sound-forms give us?

Direct inspection reveals such attributes as flatness, shallowness, roundness, bluntness, sharpness, pointedness, breadth, depth, volume, mass, shape, abruptness, smoothness, vagueness, clearness, and others; in each of which the degree of quality may vary. Such attributes, in the plan here followed, are secondary, since they depend upon the co-existence of the three primary attributes. Physiologically we have evidence of the existence of tone-forms in the sound patterns of various investigators (11, 12, 13); psychologically their presence is revealed by introspective data (14, 15); theoretically it is proved by an appeal to other sense departments. In touch, a "sharp" quality of sensation is produced when the ratio of transtensity to intensity is very small, as in the case of a pin-point or a knife-edge. A "flat" or "blunt" sensation, on the other hand, is produced when this ratio is greater, as in the case of a block of wood placed evenly against the skin. A "round" sensation, whether we use muscular activity or not, is produced when great intensity shades gradually into weak intensity or vice versa. In vision, too, a "flat" quality results from maximum transtensity and uniform intensity—a condition experienced when we view a distant, large, and uniformly illuminated wall, or the unclouded sky; a "sharp" quality results from maximum intensity and minimum transtensity—a condition found when we focus light rays upon a minute bit of chalk. Roundness is the gradual shading off of maximum brightness into minimum brightness. A ball, when viewed monocularly with complete elimination of shadows, appears flat, roundness depending upon gradual changes in light and shade. An edge is sensed as sharp when one degree of brightness stops abruptly and another degree begins as abruptly.

Thus combinations of the three primary attributes produce identical sensations of quality in three sense departments. This community of attributes is strong presumptive evidence in favor of a theory basing quality upon sensation-form.

VARIATION IN QUALITY ALONG THE PITCH SERIES

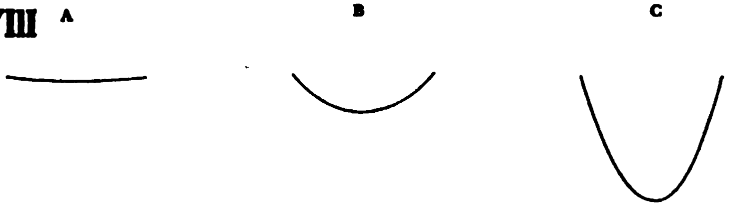
The physiology of the cochlea makes a constant ratio between intensity and transtensity impossible. The spatial arrangement of the vibrating tectorial membrane with respect to the underlying hair-cells does not permit constancy of variation (16, 17, 18, 19, 20). Intensity variations would necessarily involve variations in this arrangement. Considered only in its fundamental principle, vertical variation is much more restricted than horizontal variation because of the relative positions of the membrane and the recipient hair-cells. On the other hand horizontal variation, that is, variation in the extent of tectorial membrane involved in the response, may be considerable. It follows that variations along the pitch series are not, in themselves, accompanied by proportionate variations in the intensity series. In other words, the ratio between the two is not a constant. Moreover, the physiology of the cochlea is such that as transtensity increases, intensity increases at a much slower rate, if it increases at all. As a result, the tone or sensation-form is not constant throughout the pitch series, but changes gradually from relatively sharp forms for small stretches of transtensity to relatively blunt forms for larger stretches of transtensity. This is shown in the diagrammatic illustrations already given. High tones, therefore, partake of the characteristics or qualities associated with relatively sharp tone forms. High tones are almost universally described as thin, sharp, keen, or pointed. Low tones, since they are present in consciousness as the result of great transtensity and relatively small intensity, partake of the characteristics of the tone-forms represented by this combination, namely, flatness, volume, breadth; and are often described as large, broad, and diffuse. In the middle pitch-region, roundness and fullness describe the predominating tone-form. A fair idea of this quality distribution is given by the tones of any musical instrument of sufficient range. The variation in quality, in this sense, is continuous.

VARIATIONS IN QUALITY ALONG THE INTENSITY SERIES

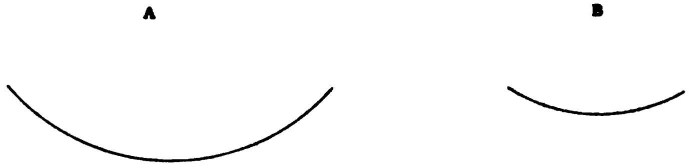
The physiological theory here adopted means that a change in intensity need not, in itself, involve a change in transtensity. Accordingly, a very weak tone might have a form such as figure 8, *a;* a moderately loud tone, of the same pitch, figure 8, *b;* and a very loud tone, figure 8, *c.* Thus, as we pass along the intensity series from weak to strong, we traverse, as in the case of pitch, a series of qualities passing from flat through round to sharp.

A consideration of the interaction of the two attributes of transtensity and intensity leads to the question: If quality results from sensation-form, do two or more similar forms produce the same quality? If they do, then a moderately loud low tone should have, let us say, the same quality as a weaker higher tone (fig. 9). This would be so if varitions in both dimensions occurred concomitantly; but, since the structure of the cochlea makes this impossible, similarity of form for two degrees of either intensity or transtensity cannot occur, and two tones of differing pitch or intensity cannot have the same quality.

VIII



IX



PROTENSIVE VARIATIONS IN QUALITY

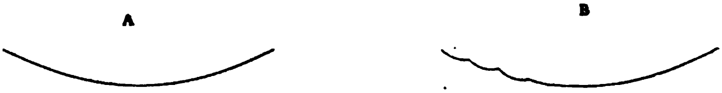
Protensity affects quality in tone-beginning, tone-duration, and tone-ending. Zero stimulation followed at once by maximal stimulation involves an immediate transition from one extreme of tone-form to the other extreme. Such abruptness, since it makes too great demands upon the physiological structure, is unpleasant. It is best described as "shock." A gradual transition does not have this unpleasant feeling-tone. If sufficiently slow, a gradual transition may permit a number of the intervening tone-forms, and hence qualities, to be present to consciousness, each of which would involve qualitative distinction. Similar changes take place with cessation of tone. For consciousness, tone-form or sensation-form is not only a "set" form but at the same time a form that has "come into being" and "passed out of being." It is true that, when tone duration is sufficiently great, the qualitative variations of tone-beginning and tone-ending (*anklingen* and *abklingen*) are relatively less important than when the tone itself is of shorter duration.

COMPLEXITY OF TONE-FORM

Thus far all tone-forms have been considered as simple. They give rise to unanalysable sensations. They contain no points or parts that are distinguishable for consciousness. In life, however, certainly in the art of music, such tone-forms are seldom met with. For the physical stimuli of musical tones are complex, that is, they contain more than one pitch. Sensorially more than one point along the transtensity series must, therefore, be marked. The tone-form then becomes divided (fig. 10) Each point along the series is a point of orientation for consciousness. If it were not, then the simultaneous presence of several pitches would produce the same sensation as the existence of the extreme pitch alone—which is not true. Such points tend to "fill out" what would otherwise be an undifferentiated sensation-mass. These differences are reflected in musical terminology. The sound of a blown bottle or tuning fork is termed *pure;* which means, in this case, undifferentiated or unanalysable. The tone of the voice or the violin, on the other hand, is described as *rich* or *full,* both meaning the presence of numerous points. Again, the tone of a tuning fork is usually described as smoother, let us say, than that of the oboe. The former would be represented physiologically, by the form shown in figure 11, *a*,; the latter, by figure 11, *b*. These, too, are but diagrammatic illustrations of the principle involved and do not represent specific conditions (21, 22). Smoothness results from an undivided tone-form; roughness, from a divided one. Other senses verify this analysis. A smooth object in vision is an object presenting uniform brightness (intensity) to the eye; a rough object is one presenting at least several degrees of intensity. In touch, an object is smooth when it presents uniform intensity to the skin, whether it rests motionless or the finger be moved over its surface; an object is rough when its parts present various intensities. A glass surface is smooth because it presents a uniform pressure (intensity); a file is rough because points of maximum intensity (the points or ridges of the file) are separated by points of zero intensity (the troughs of the file).

X

XI



This complexity of tone-form permits a very wide qualitative variation. Any one or more of the simple forms that combine to make the complex form may vary to any degree, and along any one or more of the three primary dimensions. Again, the selection of the smaller or partial tone-forms is predetermined in part by nature's series of overtones, which adds yet another variant to the others.

Feeling-tone varies also with the complexity of tone-form. A simple tone-form, since the physiology of the end-organ is well adapted to it, is physiologically pleasant. It involves a minimum of adaptation and attention. On the other hand it cannot long hold the attention because there are no points upon which attention can lay hold. A tone-form of moderate complexity is, purely physiologically considered, less pleasant than a simple tone-form, other things being equal. For the same reason a very complex form is more unpleasant because it places a greater strain upon the end-organ. This physiological unpleasantness must not be confused with the more complex pleasantness resulting from the usual complex reaction to music, which may even directly reverse the feeling-tone just described.

FEELING-TONE OF THE SECONDARY ATTRIBUTES

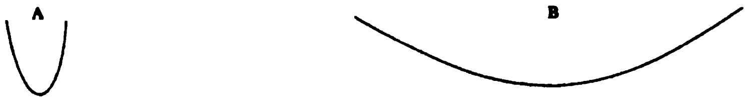
The pleasantness or unpleasantness of secondary attributes must result from variation in tone-form, for the latter is the physiological basis of all secondary attributes. Tone-form, as we have seen, may vary in many ways; the determinants of the character and the degree of feeling-tone however, are but two variants: the ratio between any two of the primary attributes, and the degree of complexity of the tone-form. Since every sensation contains the three primary attributes, organic response must be adapted to this simultaneous existence of the three dimensions. The efficiency of end-organ reaction is measured not so much by variation along any one primary series as by complex variation along the three series. Nor can this efficiency be the same for all degrees of this complex variation; here, too, as in the simple series, we find the response varying, decreasing in efficiency as we approach physiological limits. The greater the difference between transtensity and intensity, for example, the less adapted is the organ to efficient response. A tone-form (fig. 12 *a*) which represents this relationship, obviously places a greater strain upon the recipient organ than a tone-form such as that represented by figure 12, *b*, which illustrates a more equal distribution of the two extensities. The former demands almost complete isolation of the markedly affected part from the immediately adjoining parts, a condition which requires a maximum of physiological plasticity. The latter allows for a "spread" that is characteristic of all reaction, physiological in particular. This variation in ease of response colors the sensation either pleasantly or unpleasantly. Those sensation-forms are most pleasant which represent a moderate ratio between their primary attributes and a moderate absolute value of all primary attributes (10, 14, 15). Maximum presence of one primary attribute combined with minimal presence of another produces a tone-form which, through physiological strain, is sensed as unpleasant. In the differences of tone-form we have the physiological explanation of the distribution of feeling-tone described under the primary attributes.

That it is the sensation-form and not solely the absolute value of any one primary attribute, which colors the feeling-tone, may be shown in kinaesthesis. A point, such as that of a pencil, when pressed against the skin sufficiently hard, causes an unpleasant sensation. If we take a disk, with rounded edge and a hole in the center sufficiently large to permit the pencil point to pass through, and press even more strongly than we did before, the sensation is less unpleasant. In this case we have actually increased the intensity and, were the absolute value of any primary attribute the sole source of feeling-tone, the sensation, with increase of intensity should grow more unpleasant. It does not do so, because in the case cited, we have increased transtensity also and have changed the tone-form as indicated in figure 13, *a* and *b*. It is for this reason that low tones, no matter how great their intensity, cannot assume the "cutting," "sharp" character of loud high tones. Their fundamental spread, equivalent to bluntness, is too great.

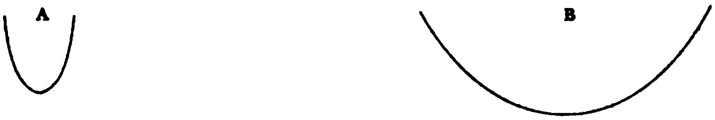
In short, then, the feeling-tone of secondary attributes, in so far as this is determined by the tone-form, distributes itself in a manner similar to that found for the primary attributes, namely, relative unpleasantness at each extreme and relative pleasantness along the middle of the complex series. Tone-forms typical of unpleasant feeling-tone may be represented as in figure 14, *a* and *b;* a form typical of pleasant feeling-tone as in figure 14 *c*.

The second determinant of the feeling-tone of secondary attributes is the complexity of the tone-form. A simple tone-form, that sensation type resulting from the waves corresponding to a single pitch (illustrated approximately by the tone of a tuning fork or a stopped organ pipe), is physiologically pleasant because the end-organ is well adapted to the mode of action demanded by this stimulus. As we increase the complexity of the tone-form we decrease the pleasantness of the sensation, because each increase in complexity demands a more finely differentiated organic reaction, which is normally colored unpleasantly by the added physiological strain involved. This forces the conclusion that the simple tone of a tuning fork is more pleasant physiologically than the complex tone of a violin—a comparison that flatly contradicts experience in modern artistic music. The contradiction, however, may be explained. In the first place, the biological reason for the added unpleasantness of complex tone-form results from the similarity of some parts of these complex tone-forms to the unpleasant types discussed under simple tone-forms. Thus, if a certain partial pitch is very intense compared to the remaining pitches we might get a form somewhat like that represented in figure 15, in which the maximal stimulation of one section of the tectorial membrane and the simultaneous minimal

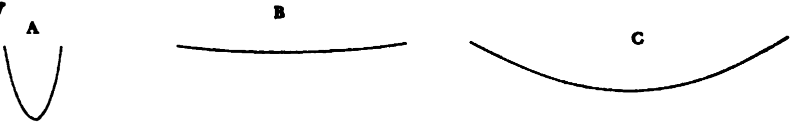
XII



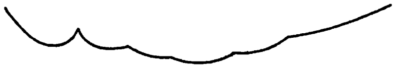
XIII



XIV



XV



stimulation of adjoining parts is the cause of the unpleasantness. All such types can be explained on the basis of the ratios among the extensities outlined for simple tone-forms. In the second place, we have evidence of the physiological pleasantness of simple sensation-form in the pleasures of infancy and early childhood. Pure colors in vision, smooth surfaces in touch are undisguised sources of pleasure at these ages, and both pure colors and smooth surfaces are sensorially equivalent to simple sounds in hearing, all of them resulting from simplicity of sensation-form. Moreover, the age of infancy is chiefly centered around sensation. In the third place, it can be shown that the added increment of pleasurableness associated with sensorial complexity for the normal adult is an acquired taste; or, what amounts to the same thing, a modified physiological reaction (10, 23, 24, 25).

In the descriptions of differences of simple and complex tones, the word "interesting" frequently occurs. This gives the key to an analysis. A simple tone-form is in itself an undifferentiated sensation-mass. There are no "points" at which consciousness can take hold. Such a sensation type, since it cannot furnish the attention with new material, soon loses interest for consciousness. A complex tone-form, on the other hand, presents a differentiated sensation-mass to consciousness, and attention may be directed first to one point and then to another. It is a richer experience, gains in interest accordingly, and becomes a more intelligible something, since it presents us with a greater mass of sensorial data. In consequence we find complex tones appealing to us more than simple tones. When we carry the complexity too far, what was at the lower extreme undifferentiated becomes so highly differentiated that consciousness cannot analyse it adequately and we return to unpleasantness again. The exact degree of complexity for maximal pleasurableness is not fixed, either for the individual or for man in general. One of the many interesting psychological aspects of music, of which musical history furnishes unmistakable evidence, is the steady progress of this degree of pleasurableness from less to greater complexity—a transition resulting from the biological law that repetition of a harmless stimulus is accompanied by less and less intense reaction, approaching complete indifference as a limit (9). Most musicians pass through a similar experience. The pleasure derived during childhood and youth from simple tone ratios, is later replaced by that resulting from more complex tone combinations. A complex tone is more pleasant in music than a simple tone because it holds the attention better, and thus eases listening, and not because it is in itself physiologically more pleasant. The added pleasure results from a change in central activity, not peripheral.

TERTIARY ATTRIBUTES

Tertiary attributes are those attributes read into tonal sensations through the action of sensations, present or past, of other sensory fields. A tone, per se, is neither "brittle" nor "feathery," yet both terms, and many others, are applied to tones, and convey, at least in many instances, a sufficiently definite meaning to make their use intelligible. An analysis of tertiary attributes is important because this class of attributes forms the threshold of musical imagination, and imagination in turn, of musical enjoyment.

Tertiary attributes are made possible by association. The doctrine of association means finally that a miscellaneous number of sensations becomes ordered and grouped in consciousness. This ordering and grouping takes place through association by contiguity and association by similarity. Applied to the problem in hand, this means, first, that whatever sensations in other fields are received simultaneously with, or in close time proximity to an auditory sensation, become linked with the latter, so that any subsequent excitation of any one of these sensations tends to arouse the others; and secondly, that sensations possessing similar elements or an element common to a third sensation are also grouped so that subsequent arousal of any one tends to awaken the others.

In order for association to function in adult life it is not necessary that conscious rehearsal and analysis of each step in the process should occur. In fact, such a procedure is often difficult if not quite impossible. But—and this is of equal importance—

it does not follow that the original chain of association was forged without awareness of its separate links. However subtly the association functions when once established, it could not have become established save through the activity of consciousness. This we must infer from the nature of the problem; an inference the correctness of which may be shown by an appeal to the age when associations are still in the making, namely, the age of infancy or early childhood. At this age intelligent children often are able to trace each step in the associative process. When thus revealed, the association becomes a purely objective, mechanical process, which, however, normally functions so rapidly that to the lay observer it is a "subconscious," "instinctive" process. Moreover, as experiment has shown, such children, as they get older and thus command a greater variety and manipulation of association, find it increasingly difficult to trace out the various steps in any but an entirely new association. An instance will make this clear. A child of six years had memorized a little piece for piano, a melody and accompaniment in G major. Upon being asked to begin on F, which placed the piece in D flat major, she made the transposition with but two errors. The readiness with which the transposition was made led to the inference that it was an "instinctive, ready-made" transfer. Subsequent questioning brought out the fact that it was the relationship between black and white keys—so many keys between this tone and that one—the use of the key near the beginning in the right hand, and the use of the symmetrically situated key for the left hand later on, which were the sources for transfer. In other words, it was a purely objective, mechanical procedure. Several years later, when the child had enriched her keyboard associations, most of which functioned automatically then, she failed to analyse the component steps when similar tests were given, answering in the familiar words: "I just do it."

The importance of establishing tertiary attributes on an objective, sensorial basis is evident when we consider them in relation to musical enjoyment. The associations awakened by music are often extremely complex and in their normal operation for the adult usually defy analysis. But it does not follow, as the foregoing case illustrates, that originally they demanded for their formation anything further than the usual psychological reaction in general. Failure to trace the associations to their source, *while they were in formation,* alone is responsible for their later inexplicableness.

Since it is not our purpose here to trace particular associations to their sources, but rather to point out the principles upon which they operate, little further need be said about associations through contiguity. Whatever impressions occur concomitantly with the auditory impression are associated with it, and it with them. The tone of a shepherd's pipe may reach the ear of one out for a pleasure stroll, and also the ear of one at the bedside of a dying friend. Henceforth, the tone of this instrument will have vastly different associations for the two, intellectually and emotionally. The operation of this type of association will be made clear to any one who takes the trouble to reflect sufficiently upon his own experience.

Association by similarity functions in two ways: between similarities in the auditory field, and between similarities in the auditory and some other sensory field.

Of primary importance are the associations formed through similarity of sensation-form. The terms apply to a particular sensation-form, regardless of the sense department in which it occurs. If a certain word describes a particular sensation-form in vision, let us say, that same word can be, and as a matter of fact is applied to a similar sensation-form in other sensory fields. I select as an example an attribute which we find in a number of investigations of tonal attributes, namely, "brightness." We meet it in Révész, Stumpf, Koehler, Meyer, Ogden, Rich, and others, (25, 26, 27, 28, 14). In the reports of these investigators we find more or less contradictory statements as to the nature of the attribute of brightness. Its true status as a secondary attribute of sensation and a tertiary attribute of audition will be revealed if we seek this explanation in terms of sensation-forms. In vision, brightness is produced by a sensation-form of great intensity as compared to its transtensity. The same sensation-form is responsible for the application of brightness to sensations in the field of audition. Brightness is a marked attribute of high tones, not of low tones; and the analysis of tone-form which we made under secondary attributes shows an increasing ratio of intensity to transtensity as we ascend the pitch series. This change in tone-form is the cause of the brightness attribute. Again, sharpness in kinaesthesis results from a sensation-form of relatively great intensity and minimal transtensity; it is the equivalent of brightness in the visual field. Accordingly, we find "sharpness" also applied to tones when the particular tone-form just described is present. This association-scheme is shown by everyday observation and by the introspective remarks of subjects tested under control conditions. Thus Preyer (30) writes that the hearing of the highest tones is accompanied by sensations of pain, as if the ear were pricked with a fine needle; and Stumpf (25): "we have to differentiate a third moment which may be designated 'brightness,' and analogous to the brightness of color." (The fact that the term brightness was applied to tone before it was applied to colors, does not invalidate the conclusion here drawn, but merely robs vision of its priority in this respect). In the introspections of other subjects (14) we read "I feel that the pointed focused tones are brighter;" "tone appears to be brighter or duller, also sharper or blunter;" "some tones are brighter, but brighter may be sharper;" "bright means sharper;" "brightness is the emergence of the salient from the volumic mass." Or, selecting random remarks of piano pupils: "the tone has an edge like a knife;" "the tone reminds me of a spark;" "it hurts like a bright light or a point."

Let us take another attribute: hardness. Its application in audition is found in such well-known phrases as: "his tone was hard;" "the hardness of the tone was unpleasant;" "at times the tone became as hard as nails." In the auditory field hardness is a tertiary attribute applicable here through association with kinaesthesis. In the latter sensory field an object capable of retaining a form of relatively great intensity, is hard. If it were not, it would flatten out upon pressure. Hardness can be sensed only when accompanied by considerable pressure; light pressure against an object will not determine its hardness. A sensation-form in audition, similar to the one given for kinaesthesis, is the form resulting from a relatively loud tone. Therefore, hardness becomes an attribute of great intensity, or the sensorial equivalent, loudness. In an experimental study and analysis of piano tone and touch, recently made (31), this relationship has been shown to exist in every case. Hardness, in these experiments, was always accompanied by a relatively great intensity. In the following table an attempt is made to analyse into their fundamental attributes, a few of the many tertiary attributes of tone. Neither the list of attributes is complete, nor are the sources of their derivation; but a sufficiently varied list is given to explain the principle upon which tertiary attributes are developed. In certain cases the analysis has been verified by experimental procedure.

A second important group of tertiary attributes is that formed by spatial association. It divides into three sub-groups: the high-low distribution; the near-strong, far-weak association; and the near-high, far-low association.

Tones are more often described by "high" and "low" than by any other term. In fact, when we discuss songs, it is difficult to keep away from all aspects of this spatial distribution. So much so, that height and depth have at times been considered primary attributes of tone. The standard test for pitch discrimination (32) uses the word "higher" in the instructions; a glance at the introspection of laboratory subjects will reveal further the extent of this spatial association. The latter has a world history. We find it with the Chinese, the Indians, the Isreaelites, the Greeks, the Romans, and all western civilization, and it is reflected in all known systems of musical notation, including, of course, our own. Yet in spite of this wide-spread and old association, we may not infer that height and depth are primary attributes of tones. A brief consideration of this association will make this clear.

Physiologically there is no direct basis for an elevation attribute in audition. The spiral shape of the cochlea and the direction of its modiolar axis (descending slightly towards the apex when in normal position) preclude any direct spatial distribution

TERM	SENSATION-FORM	SOURCES OF ASSOCIATION
Feathery	Minimal intensity	Vision; kinaesthesis
Rich	Moderate complexity Moderate intensity Moderate transtensity	Vision (complexity resulting from differentiation of parts); kinaesthesis
Dull	*a*. Small intensity in relation to transtensity. *b*. Minimal complexity in relation to protensity.	Vision; continuity in any sensory field
Colorful	Moderate to high complexity	Vision
Forced	Great intensity	Kinaesthesis
Clear	Sharpness of sensation-form Moderate to great intensity	Vision; kinaesthesis; smell
Crisp	Minimal protensity	Vision; clearness of definition; temperature; audition: phonetics
Pinched	Maximum intensity, minimum transtensity	Kinaesthesis
Noisy	Maximal complexity	Audition
Pushed		Direct transfer from vision and kinaesthesis
Brittle	Sharpness of tone-form	Vision; kinaesthesis
Glassy	Relatively great intensity; sharp definition of tone-form	Vision; kinaesthesis; (see *clear*)
Sparkling	Minimal protensity or minimal transtensity	Vision; audition: volume
Singing	Marked protensity with fixed sensation-form	Kinaesthesis: vocality
Hollow	Simplicity of tone-form	Vision
Sour		Taste and kinaesthesis

which would account for the high-low association. An indirect basis is found in the sensation-form. The extensity theory of pitch assigns a greater extent of vibrating tectorial membrane to low tones, that is, tones of small frequency, than to tones of great frequency. Accordingly, low tones are more extended, larger, more voluminous, than high tones. This fact introspection reveals beyond any doubt (14, 5, 15, 25). But vision and kinaesthesis teach us that, normally, large objects are below small ones; that of two objects of the same material the larger is the heavier. Also that sounds of small frequencies are produced by large bodies: cannon, large organ-pipe, double-bass; those of great frequencies by small bodies: small organ-pipe, violin. Man's voice, too, is lower than woman's and man is the larger animal. Finally, the principle of resonance—as the result of the operation of which large hollow spaces reinforce low frequencies, small spaces great frequencies—strengthens the association between pitch and space.

The bodily-distribution theory explains the high-low aspect on the basis of the positions assumed by the vocal organs, as exemplified in expressions such as *head voice*, *chest voice*, *falsetto*. For the production of high tones, the organs are elevated, for that of low tones they are depressed. The strain-relaxation theory places height and depth upon the muscular strain and relaxation involved in tone production and associated with the strain and relaxation accompanying the movement of the body through space. In either theory we are dealing with kinaesthetic association.

Neither the instrumental theory, which developes the high-low association from the manner in which instruments are played nor the notation theory which finds the source of the association in musical notation, is plausible. The instrumental theory is not plausible because musical instruments are played in all directions, ascent for the violinist is descent for the cellist, horizontality to the right for the pianist, is horizontality to the left for the flutist; the notation theory is not plausible, because the high-low aspect considerably antedates known systems of musical notation.

Tones are "high" and "low" through the operation of a complex chain of visual, auditory, and kinaesthetic association; and since these are the basis for our last class of tonal characteristics, "height" and "depth" become tertiary attributes of tone. As a result of this spatial distribution, tones assume the characteristics of other objects possessing the same attributes. *Ethereality, heavenliness, profundity, gravity,* for example, thus become applicable to the single tone.

The near-strong, far-weak association

Physically, a wave decreases in amplitude as it recedes from its source. Sensorially, a sound, in consequence of the operation of this law, becomes weaker as the distance between the source of sound and the hearer increases. Of two sounds of equal source-intensity, therefore, the nearer is the louder. As the high-low distribution transfers the vertical dimension of space to the auditory field, so the near-strong distribution transfers the depth or distance dimension of space into the auditory field. With this transfer we get a further group of associations: a tone may now be projected to any point in a horizontal plane the center of which is the hearer; and each projection awakens, through association by visual similarity, associations previously made with that particular distance. *Hazy, veiled, mysterious, clouded, far-off, intimate,* are some of the terms applied to tones as a result of the near-strong, far-weak association.

The near-high, far-low association

The two spatial relationships just described do not always function independently. They are at times complicated by a qualitative distribution, as a result of which near tones assume a high quality and far tones a deep or low quality. The physical basis for this correlation is found in the fact that shorter wave lengths are more rapidly damped than longer waves. Accordingly the high partials of a complex sound may be damped before the disturbance reaches a distant observer. At any rate, other things being equal, the waves corresponding to the high partials will be annihilated before the lower frequencies, so that a complex sound wave, as it passes through the air, undergoes a change in complexity (the physical equivalent of sensorial quality), passing from greater to less complexity, with the sine-curve as a theoretical limit. In consequence, the farther the hearer is from the source of sound, other things being equal, the lower is the sound, for the fundamental is the lowest tone of the harmonic series. Practical verification of this theoretical principle is found in sounds with which every one is familiar (35). When the source of thunder, for example, is distant, the sound heard is a rumble; when the source is near, the sound heard is a crash. The sound of an approaching wagon changes from a rumble to a rattle, and as the wagon recedes changes back again into a rumble. Both "rumble" and "crash" or "rattle" are phonetics; the former centering round the pitch of "u" as in rumble and the latter around the definitely higher pitch of "a" as in crash or rattle. Again, when standing near a steam whistle a complex sound containing high pitches is heard; at a distance only the lower pitches remain audible. These examples illustrate the far-low, near-high array. As a result of such a distribution the position of a tone in space is not only determined by its pitch and its intensity, but also by its secondary attribute of quality.

The feeling-tone of tertiary attributes

The feeling-tone of the tertiary attributes just described is determined on one hand by the sensation-form which gives rise to the attribute, and on the other hand by emotional complexes, coloring, more or less vividly, the association involved. Sensation-form here functions similarly to the sensation-form discussed under secondary attributes: extreme brightness or dullness, for instance, being, in itself, more unpleasant than intermediate degrees of brightness or dullness (36). The emotional coloring of the complexes mentioned, for instance of the spatial associations, since it is only indirectly physiological, does not lend itself to a simple classification. For our problem we need not determine the sources of these associational feeling-tones, which often are essentially non-auditory in character. Whether height is pleasantly or unpleasantly tinged, whether distance awakens longing or repulsion, whether darkness awakens fear or repose, need not detain us. These are problems dealing with secondary attributes in other sensory fields. Any one of these emotional colorings, and many more which we have not mentioned, may be present, and each one colors the particular tone or attribute more or less characteristic of it. As a result of the influence of these complexes, a single tone, even, may express longing, remorse, and what not. Nay, even more. Since such attributes are tertiary, that is, essentially dependent upon association with other sense departments, the same tone may express beauty to one, ugliness to another, and neither beauty nor ugliness to a third. The associations upon which such attributive assignment depends, may originate at any point in past experience, and therefore these associations will differ as much as the experiences of mankind in themselves differ. And yet, in spite of this enormous complexity, the latter could, if we had sufficient data at our disposal, be traced down the scale of attributes and analysed into secondary and primary attributes equivalent to those here described for audition.

Thus most of the so-called "characteristics of keys" result from the operation of tertiary attributes, and the interesting cases of synaesthesia are further examples of these associational complexes. In fact, the entire problem of individual differences in musical appreciation is intimately connected with tertiary attributes. For the primary and most of the secondary attributes are in a way, common to all persons, accompanied, at the most, by variations in degree. Without minimizing the influence of these quantitative variations, marked qualitative variations among individuals are the chief characteristic of tertiary attributes. In other words, the differences in emotional reaction to music cannot be explained on an auditory basis alone, but involve the entire sensorial complex of the field of sensation.

CONCLUSIONS

The analysis of the sensorial basis of music appreciation which we have made, is itself not entirely free from unsolved problems. Nevertheless, it enables us to draw certain conclusions which may help in the construction of a psychology of the more complex reactions to music.

In the first place, the analysis shows the impossibility of basing an adequate psychology of music appreciation upon purely auditory grounds. An important part of the enjoyment of music, as presented today, is non-auditory in character.

In the second place, a psycho-physiological basis for individual differences is given that demands, for its development, only the operation of accepted principles of association.

In the third place, the discrepancies in studies of tonal attributes dealing with terms such as "brightness," "roughness," are explained. Such terms are secondary, not primary attributes, and are therefore further analysable.

Finally, the attributive analysis of tones here given, materially simplifies the problems of the complex reactions to music. Many phases of music enjoyment, assigned to the inspired character of a particular composition, are, as a matter of fact, the direct effects of the primary, secondary, and tertiary attributes of tones. The attributes of the separate tone form the real basis of auditory reaction, and through this, of musical enjoyment in all its complexity.

REFERENCES

(1) **Dunlap, K.**: Extensity Theory of Pitch, Psy. Review xii, 1905, Psy. Bulletin 6, 58, 1909.
(2) **Ewald J. R.**: Erzeugung von Schallbildern in der camera acoustica. Arch. d. Ges. Physiol., lxxvi, 147, 1899; xciii, 485, 1903.
(3) **Schambaugh G. E.**: On the anatomy of the cochlea. Amer. Jour. Anat., vii, 245. 1907.
(4) **Hardesty J.**: Amer. Jour. Anat., viii, 109, 1908.
(5) **Watt, H. J.**: The Psychology of Sound.
(6) **Göbel O.**: Uber die Tätigkeit des Menschlichen Hörorgans, Arch. Ohrenheilkunde, 87, 1911, 90, 1912.
(7) **Lehmann A.**: Über die Schwingungen der Basilar-Membran. Folia Neurobiol., iv, 116, 1910.

(8) **Ter Kuile** E.: Übertragung der Energie von der Grundmembran auf die Hörzellen. Arch. d. Ges. Physiol., lxxix, 146, 1900, lxxvi, 608, 1899.
(9) **Ladd**: Physiological Psychology.
(10) **Ortmann** O.: Types of Reaction to the Presentation of Music.
(11) **Ewald**, J. R.: Op. cit.
(12) **Lehmann** A.: Op. cit.
(13) **Watt** H. J.: Op. cit.
(14) **Rich** G.: Study in tonal attributes. Amer. Jour. Psych., xxx, 1918, 121.
(15) **Brentano** F.: Untersuchungen zur Sinnespsychologie.
(16) **Retzius** G.: Das Gehörorgan der Wirbelthiere.
(17) **Hansen** V.: Physiologie des Gehörs. Hdbuch d. Physiol.
(18) **Waetzmann** E.: Über die Ausdehnung d. Töne. Folia Neurobiol., vi, 24, 1912.
(19) **Schaefer** K.: In Nagel's Hdbuch d. Physiol.
(20) **Ewald** J. R.: Physiol. Untersuchungen über d. Endorgan d. nervus octavus.
(21) **Miller**, D. C.: The Science of Musical Sounds.
(22) **Helmholtz** H.: The Sensations of Tone.
(23) **Riemann** H.: Hdbuch d. Musikgeschichte.
(24) **Bolton**, W.: Studies in Rhythm.
(25) **Stumpf**, C.: Tonspychologie.
(26) **Révész** G.: Zur Grundlegung d. Tonpsychologie.
(27) **Stumpf**, C.: Über neuere Untersuchungen zur Tonlehre.
(28) **McDougall** W.: Physiological Psychology.
(29) **Titchener**, E. B.: Psychology.
(30) **Preyer**.: Grenzen d. Tonwahrenhmung.
(31) **Ortmann**, O.: Physical Aspect of Piano Touch and Tone.
(32) **Whipple** G.: Manual of Mental Tests.
(33) **Pieron**, H.: L'evolution de la Memoire.
(34) **Jennings**.: Behavior of the Lower Organisms.
(35) **Abraham**, O.: Wahrnehmung kürzester Töne U. Geräusche. Zeitschrift Psych., xviii, 177, 1898.
(36) **Squire**.: Genetic Study of Rhythm, Amer. Jour. Psych., xii, 492. 1901.

THE RELATION OF DEGREE OF INDIAN BLOOD TO SCORE ON THE OTIS INTELLIGENCE TEST

WALTER S. HUNTER ASSISTED BY ELOISE SOMMERMIER
The University of Kansas

INTRODUCTION

The present paper reports the application of the 1919 edition of the Otis group intelligence test to 715 American Indians in school at the Haskell Indian Institute, Lawrence, Kansas.[1] It was our intention to compare not only Indian scores and white scores but also the scores made by the various degrees of Indian blood. It was not our intention to determine what psychobiological functions the Otis scale measured, nor to examine the fineness of its measurement. We have taken this scale as one of the best available group intelligence scales, and have critically examined its diagnostic value when applied to the detection of significant differences in ability between the various degrees of blood. The study is a contribution to the experimental study of racial differences in behavior. It also throws light upon the topic of "the inheritance of general intelligence" inasmuch as the results indicate that the ability involved in the Otis test decreases with a decrease in the amount of white blood.

We have felt certain in our own minds that no available scale is sufficiently accurate to indicate the fineness of the differences that may exist. The positive results which we have secured would therefore indicate that the differences between the degrees of blood are greater than our tests reveal. As the present account proceeds, we shall indicate other reasons for believing that our results under- rather than overstate the case.

---

[1] This study was made possible by a money grant from the Research Committee of the University of Kansas Graduate School and by the courtesy of Supt. H. B. Pears of Haskell Institute. It was first reported in the Psychological Bulletin, 1921, xviii, 91–2.

SUBJECTS

The 711 Indian subjects for whom blood data were available are grouped as follows: pure Indian blood ($\frac{4}{4}$), 265 cases; three-quarters Indian blood ($\frac{3}{4}$), 142 cases—this includes all degrees of blood from $\frac{4}{4}$ to and including $\frac{3}{4}$; one-half Indian blood ($\frac{1}{2}$), 192 cases—this includes all cases less than $\frac{3}{4}$ to and including the $\frac{1}{2}$ bloods; one-quarter Indian blood ($\frac{1}{4}$), 112 cases—this includes all Indians of less than $\frac{1}{2}$ blood. Only 7 subjects were less than $\frac{1}{4}$ Indian, and none was less than $\frac{1}{16}$. The degree of blood was determined in all cases from the official records of the school and is thus stated with a minimum of error.

Distributions for age and school grade will be given later in the paper (pages 262 and 276). The school grades taught begin with the fourth and extend through the tenth, after which come two years of commercial work. A grade designated "unclassified" contains a few elementary students whose exact grade status is difficult to determine at the time of their admission to the Institute. These grades are approximately one year advanced as compared with the grades at public school. The ninth and tenth grades are vocational grades, while the commercial course corresponds to the ordinary high school commercial course save that no foreign language is offered. The pupils spend one-half day in school and the other half day in industrial work.

The Haskell students tested come from many different parts of the United States and represent 65 tribes and 14 different tribal mixtures. In order to enter the Institute they must (according to the rule) be at least fourteen years old, have the equivalent of third grade schooling, and have a physician's certificate of good health. Most of the students need government aid and are admitted without tuition.

It is important in this connection to call attention to the following: It is probable that the full bloods represent the best type of pure Indian, the lower types being content to remain at home or in the reservation schools. Attendance at Haskell indicates the presence of initiative and the desire to progress. The quarter bloods, on the other hand, probably do not represent the best of their grade. The more alert and ambitious near-whites will find their way in the world without attending Haskell. One should not overlook the possibility, moreover, that the white blood present in the various hybrids is of a low grade. We have no evidence that negro blood is present.

The selective factors commented upon in the above paragraph will tend to decrease the magnitude of discoverable differences in intelligence as represented in the various degrees of Indian blood, thus making the following data even more significant than appears on the surface.

We ourselves tested no white subjects, but were supplied with extensive data by Dr. Arthur Otis. This data gave us a correlation table of age and score for 11,548 American school children. Of these, writes Otis, probably 100 were colored. No information is at hand concerning social status; but it is known that approximately the same number of students were selected from the various grades and that these grades come from 79 schools widely distributed over the United States. The ages range from eight years to eighteen years, inclusive (table 2). In addition Dr. Otis has supplied us (in 1922) with the records of 151 fifteen-year-old individuals giving the scores made by each subject on each of the ten tests. The median Otis score for the group is 130 which is slightly above that for the fifteen-year-olds of table 3. The group purports to be a random sampling for the age in question. These data enable us to compare the average white score for each test with the average scores for the several degrees of Indian blood. The discussion of this problem will be found below, page 266.

ADMINISTRATION OF THE TESTS

The tests were administered by the members of the Individual Psychology class of the University of Kansas under the direction of the writers and Miss Elizabeth Stark, Instructor in Psychology.[2] All examinations, with the exception of a few given to subjects absent at the time of the first test, were given without warning to the students. No explanation of the purpose of the tests was offered other than occurs in the printed directions which were followed literally. When the students were assembled in their respective class rooms, their teachers, who remained present throughout the examinations, instructed them to do their best on the questions asked them. We noted no sullenness or unwillingness to work. No more nervousness was apparent that is expected in groups taking intelligence tests. It is particularly to be noted that the subjects were accustomed to school room conditions.

---

[2] We wish to express our great appreciation for the help rendered by Miss Stark and the students of her class.

The school records furnished the following data for each student: name, age, sex, tribe, degree of blood, residence, school grade, and total number of months of schooling. We did not succeed in ascertaining social status, although we should be willing to assume its inferiority on the average to the social status of the whites. If anything, we should expect the social status of the near-whites who attend Haskell to be inferior to that of the near-Indians who attend, although this is almost a bare assumption.

RESULTS OF THE TESTS

The total distribution for all Indians irrespective of degree of blood is shown in figure 1. The scores range from 1 to 169 with the median at 82.64, $\sigma 36.71$. For purposes of comparison, we have selected the 1366 cases of fifteen-year-old whites furnished by Otis. This age was selected partly because of the large number of cases which it contains and partly because there were very few Indians below fourteen years of age (table 1). The median for the whites is 122.58, $\sigma 30.9$. The difference between whites and Indians is significant. Tables 1 and 2 give the correlation tables for age and score for the Otis pure white data and for the total Indian group.

The superiority of the whites over the Indians taken as a group is further shown in table 3 where the two races are compared for the ages fourteen to eighteen, inclusive. The median score, σ, and the number of cases (N) are shown.

The correlation formula[3] which we have used is in the form

$$r = \frac{\frac{\Sigma x'y'}{n} - C_x C_y}{\sigma_x \sigma_y}.$$

(In all correlations involving Indian blood only the four degrees of blood above stated were employed. A greater sub-division would in all probability raise the coefficients.) This has yielded the following results when applied to the intercorrelation of the four significant factors: (1) degree of Indian blood; (2) total score on the test; (3) age, and (4) total months of schooling:

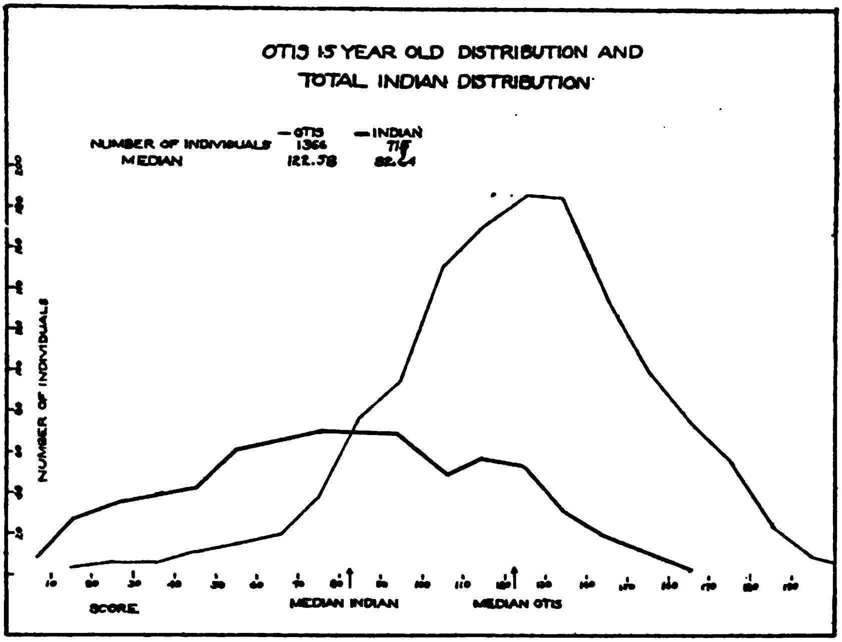


FIG. 1

$r_{12} = 0.35 \pm 0.023$ $\qquad$ $r_{23} = 0.17 \pm 0.024$

$r_{13} = 0.14 \pm 0.024$ $\qquad$ $r_{24} = 0.35 \pm 0.022$

$r_{14} = 0.000$ $\qquad$ $r_{34} = 0.45 \pm 0.020$

---

[3] Taken from Rugg, H. O., Statistical Methods applied to Education, Boston, 1917, 269.

The indications, therefore, are as follows: (1) There is a significant positive relation between degree of Indian blood and score, the score falling as degree of white blood falls; (2) there is a significant positive relation between score on the test and the total number of months of schooling which the subject has had; (3)

TABLE 1

Distribution of Indian scores by age and Otis score

AGE	0–9	10–19	20–29	30–39	40–49	50–59	60–69	70–79	80–89	90–99	100–109	110–119	120–129	130–139	140–149	150–159	160–169
11					1	1	1	1					1				
12			1			1	2		1								
13		1	2	1	2		2	1	2		2	1	1				
14		5	6	4	2	6	7	8	3	3	2	2	2	4	1		
15	3	8	2	9	9	10	14	11	5	5	5	7	10	5	2		2
16	3	3	5	5	7	11	17	14	12	13	3	12	10	2	5	2	1
17	2	4	4	6	7	5	6	11	18	14	15	14	6	5	4	4	
18	1	4	4	8	6	14	10	9	12	10	5	10	6	4	1	3	3
19		1	5	3	4	5	4	6	10	12	11	5	8	4	4	1	3
20			3	1	1	2	1	2	4	6	4	4	6	4		1	
21			2	2	1	3	1	1		2	3	1	1	1	1		
22						1		1	1	1			1	1			
23														2			
24																	
25			1														
26																	

TABLE 2

Distribution of Otis scores by age for pure whites

AGE	0–9	10–19	20–29	30–39	40–49	50–59	60–69	70–79	80–89	90–99	100–109	110–119	120–129	130–139	140–149	150–159	160–169	170–179	180–189	190–199	200–209
8	3	15	49	63	49	34	29	32	20	7	1										
9	1	26	79	68	89	92	95	88	60	36	21	14	8		2						
10	3	33	43	84	104	111	100	90	82	63	41	33	17	5	5						
11	2	10	22	44	76	102	95	122	143	116	134	96	68	45	18	9	4		1		
12	4	15	18	54	66	78	118	148	173	148	178	165	106	68	43	28	17	6	1	1	
13	3	9	17	25	44	59	79	129	149	168	196	204	175	164	125	91	45	11	3	3	
14		5	10	22	31	34	51	89	131	178	318	234	205	189	171	116	78	35	11	3	
15		3	5	5	12	15	19	38	77	95	151	171	186	184	133	101	75	57	24	11	4
16					4	4	9	21	33	53	90	127	128	183	142	113	122	68	45	33	7
17						1	1	9	11	25	46	66	101	112	95	112	98	51	25	5	1
18							1	3	3	10	21	28	34	53	73	63	46	32	21	5	1

there is a similar relation between months of schooling and age (we shall make certain additional comments upon these factors on page 273ff), and (4) there is only a small positive relation between degree of blood and age or between total score and age.

TABLE 3

Comparison of whites and Indians (all), ages 14 to 18

	MED.	σ	N
Fourteen years			
Indian	67.1	36.0	52
Whites	113.6	20.59	1915
Fifteen years			
Indian	69.28	37.42	107
Whites	122.58	30.9	1366
Sixteen years			
Indian	78.5	34.75	125
Whites	135.0	28.26	1182
Seventeen years			
Indian	89.7	34.7	125
Whites	140.78	25.99	759
Eighteen years			
Indian	79.0	37.4	110
Whites	140.6	24.49	394

Substituting the above correlation values in the partial correlation formula,

$$r_{12\cdot 34} = \frac{r_{12}\left(1 - r_{34}^2\right) - r_{13}\left(r_{23} - r_{24}r_{34}\right) - r_{14}\left(r_{24} - r_{23}r_{34}\right)}{\sqrt{1 - r_{13}^2 - r_{14}^2 - r_{34}^2 - 2r_{13}r_{14}r_{34}}\ \sqrt{1 - r_{23}^2 - r_{34}^2 - r_{24}^2 - 2r_{23}r_{34}r_{24}}}$$

we get a correlation of +0.41 for degree of Indian blood and total score with the factors of age and months of schooling constant.

If we now include the pure whites in our degrees of blood, using the 1366 fifteen-year-olds, thereby increasing the heterogeneity of the data, the Pearson formula gives a correlation of 0.64 ±0.008

for degree of blood (from pure white to pure Indian) and intelligence score. In order to reduce the number of cases in the fifteen-year-old whites to a quantity about equal to that in each degree of Indian blood,[4] we next took the distribution as given in table 2 (for the fifteen-year-olds) and divided each unit by 10. We thereby substituted for the true distribution the following one, beginning with the score interval 30–39: 1, 1, 2, 1, 3, 7, 9, 15, 17, 18, 18, 13, 10, 7, 6, 2, 1. Using these white data and that for all of the Indians gives a correlation of 0.51 ±0.017 for degree of blood and total score on the test.

This decrease of intelligence score with increasing amount of Indian blood can be presented in other forms. Thus table 4 gives the 25, 50, and 75 percentile total scores for the various bloods and figure 2 gives the total distributions for each blood.

TABLE 4

25, 50, and 75 percentile scores for each blood

PERCENTILE	¼ BLOOD	½ BLOOD	¾ BLOOD	4/4 BLOOD
25	77.25	68.0	56.31	35.8
50	109.3 σ34.0	91.47 σ33.0	77.75 σ35.0	67.46 σ47.0
75	127.9	117.9	108.3	94.35

A comparison of the medians indicates a slight but positive, consistent, and reliable difference. Figure 3 presents this graphically, including the fifteen-year-old whites.

We may present the relative standing of each blood further by indicating the percentage of each blood testing above the medians for the bloods whiter than it. Thus:

14.4 per cent of the 4/4 blood tested at or above the ¼ median
36.3 per cent of the 4/4 blood tested at or above the ½ median
43.0 per cent of the 4/4 blood tested at or above the ¾ median
23.0 per cent of the ¾ blood tested at or above the ¼ median
36.4 per cent of the ¾ blood tested at or above the ½ median
36.3 per cent of the ½ blood tested at or above the ¼ median

---

[4] This was suggested by Dr. Curt Rosenow, Associate Professor of Psychology, at the University of Kansas, to prevent the over-weighting of the calculation with white blood.

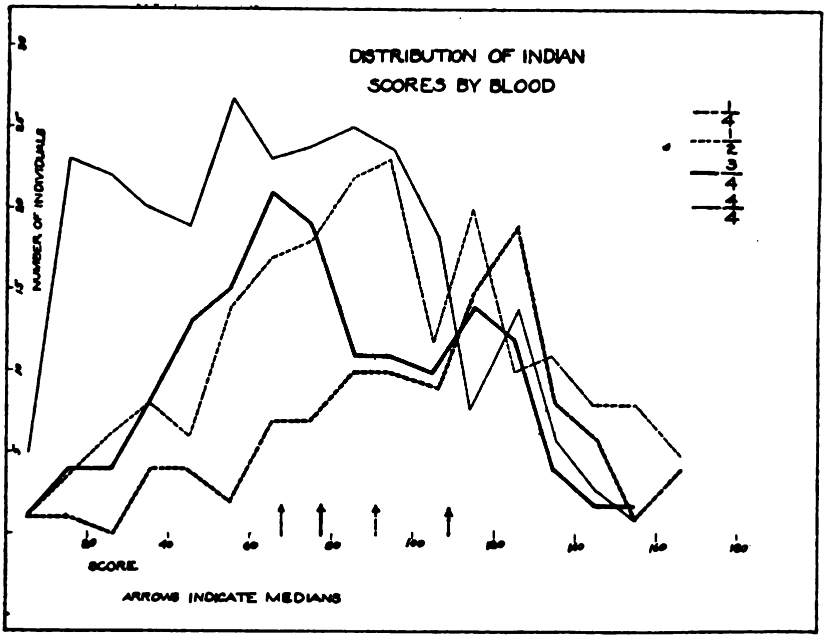

DISTRIBUTION OF INDIAN
SCORES BY BLOOD
1/4
1/2
3/4
4/4
NUMBER OF INDIVIDUALS
30
25
20
15
10
5
20
40
60
80
100
120
140
160
180
SCORE
ARROWS INDICATE MEDIANS

Fig. 2

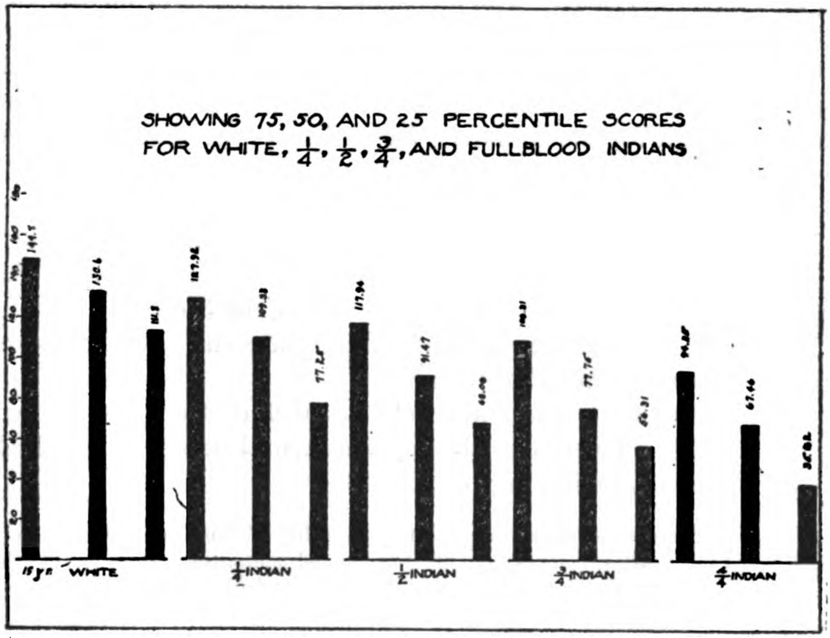

SHOWING 75, 50, AND 25 PERCENTILE SCORES
FOR WHITE, 1/4, 1/2, 3/4, AND FULLBLOOD INDIANS
180
160
140
120
100
80
60
40
20
144.5
130.6
111.5
127.92
109.33
77.25
117.94
91.47
68.00
110.31
77.76
56.31
96.85
67.44
36.82
15 yr.
WHITE
1/4 INDIAN
1/2 INDIAN
3/4 INDIAN
4/4 INDIAN

Fig. 3

In table 5 we present a detailed analysis of the relation of degree of Indian blood to score on each of the ten individual tests making up the Otis scale.[5] The data are also included for the 151 fifteen-year-old whites referred to on page 259. An examination of this table indicates, with few exceptions, a decreasing score in the three quartiles as degree of white blood decreases. This relationship is also indicated in the percentages of zero scores. Table 5 also makes possible for each test the following illuminating types of comparison: In test 1, 50 per cent of the ¼ bloods make a score only attained by the best 25 per cent of the ⁴⁄₄ bloods. Or again, the 25 percentile for the ¼ bloods in each test is usually equal to or above the median for the ⁴⁄₄ bloods, and the ¼ blood median holds about the same relation in general to the ⁴⁄₄ blood 75 percentile.

In figure 4 the medians for each blood in each test are represented graphically in terms of percentage of the possible score on that test. Thus in test 1, where the possible score is 20, the ¼ blood median is 50.5 per cent of the possible score. The other percentages are: ½ bloods, 47 per cent; ¾ bloods, 42 per cent; and ⁴⁄₄ bloods, 36 per cent. The figure also contains data for the 151 whites referred to in connection with table 5. The figure shows that tests 4 (interpretation of proverbs), 5 (arithmetic), and 6 (directions test using geometrical figures) were in general the most difficult for the Indians. Tests 4 and 6 were also the more difficult for the whites. There is some individual variation in this characteristic of relative difficulty among the Indian groups. Thus while all bloods have their lowest median in test 4, tests 7 (analogies) and 9 (narrative completion) are the next poorest for the ⁴⁄₄ and ¾ bloods, although this is not true for the other bloods. Tests 3, 5, 6, 8, and 10 do not differentiate the five degrees of blood so well as the other tests.

We believe that it is impossible to conclude from the present data anything concerning the specific mental processes in which the Indian may be inferior to the white.

---

[5] For the reader's convenience, the following list of the ten tests is offered: (1) directions test; (2) opposites; (3) disarranged sentences; (4) proverbs; (5) arithmetic problems; (6) directions test with geometrical figures; (7) analogies; (8) similarities; (9) narrative completion; and (10) logical memory.

TABLE 5

Data on score and blood on each of the ten tests

BLOOD	25 PER CENT	MED.	75 PER CENT	PER CENT 0 SCORES
Test 1				
$\frac{1}{4}$	8.0	10.1	11.7	1.7
$\frac{1}{2}$	6.8	9.4	11.9	3.6
$\frac{3}{4}$	5.5	8.4	11.3	4.8
$\frac{4}{4}$	3.7	7.2	10.0	16.6
Total medians				8.8
σ				3.8
Blood and score				r 0.28 ± 0.023
Whites	10.7	12.5	14.4	0.60
Test 2				
$\frac{1}{4}$	7.8	11.3	15.3	2.6
$\frac{1}{2}$	7.93	10.6	14.6	3.6
$\frac{3}{4}$	5.6	9.7	13.4	5.6
$\frac{4}{4}$	2.7	8.1	11.8	17.2
Total medians				9.2
σ				6.9
Blood and score				r 0.11 ± 0.023
Whites	11.0	14.9	17.8	2.0
Test 3				
$\frac{1}{4}$	8.1	11.7	14.5	5.3
$\frac{1}{2}$	6.0	10.8	14.3	7.8
$\frac{3}{4}$	5.9	9.5	12.7	11.9
$\frac{4}{4}$	2.7	8.0	11.1	15.0
Total medians				8.0
σ				4.9
Blood and score				r 0.31 ± 0.023
Whites	10.6	12.8	15.9	0.6
Test 4				
$\frac{1}{4}$	2.7	6.4	8.7	9.0
$\frac{1}{2}$	1.7	3.7	7.3	15.4
$\frac{3}{4}$	1.1	2.7	5.3	23.2
$\frac{4}{4}$	0.0	2.3	4.8	27.9
Total medians				3.0
σ				4.1
Blood and score				r 0.24 ± 0.024
Whites	5.6	9.6	12.7	3.3

TABLE 5—*Continued*

BLOOD	25 PER CENT	MED.	75 PER CENT	PER CENT 0 SCORES
		Test 5		
¼	7.5	10.0	12.2	1.7
½	6.7	9.3	11.6	0.0
¾	6.3	8.4	10.9	0.0
4/4	5.3	7.3	10.1	0.3
Total medians				7.2
σ				3.4
Blood and score				0.25 ± 0.024
Whites	10.3	13.0	15.9	0.00
		Test 6		
¼	5.3	7.5	8.9	1.7
½	4.8	6.8	8.5	1.5
¾	4.3	6.3	8.1	4.2
4/4	3.4	5.7	7.7	5.6
Total medians				6.3
σ				2.8
Blood and score				r 0.21 ± 0.024
Whites	7.4	8.8	10.7	0.00
		Test 7		
¼	6.8	11.5	14.8	9.8
½	5.5	9.5	13.5	8.3
¾	3.3	7.2	11.9	12.6
4/4	1.4	6.1	10.5	22.9
Total medians				7.0
σ				5.4
Blood and score				r 0.27 ± 0.023
Whites	11.3	13.5	16.5	0.6
		Test 8		
¼	9.2	11.4	13.8	7.1
½	7.6	10.4	13.4	2.6
	6.3	9.9	12.5	9.1
4/4	3.8	8.7	11.7	9.4
Total medians				9.7
σ				4.5
Blood and score				r 0.24 ± 0.024
Whites	9.9	11.8	13.2	1.3

TABLE 5—*Concluded*

BLOOD	25 PER CENT	MED.	75 PER CENT	PER CENT 0 SCORES
Test 9				
¼	6.8	12.1	18.6	6.3
½	5.7	9.0	14.1	10.9
¾	3.6	6.1	10.5	14.1
4/4	1.6	5.6	10.4	22.3
Total medians				10.3
σ				6.6
Blood and score				r 0.32 ± 0.023
Whites	11.5	17.3	21.0	3.9
Test 10				
¼	13.9	17.5	20.9	0.0
½	13.1	16.4	19.8	0.0
¾	10.3	14.9	17.7	0.0
4/4	9.3	13.3	16.8	0.0
Total medians				14.9
σ				4.9
Blood and score				r 0.32 ± 0.023
Whites	16.2	19.5	22.5	0.0

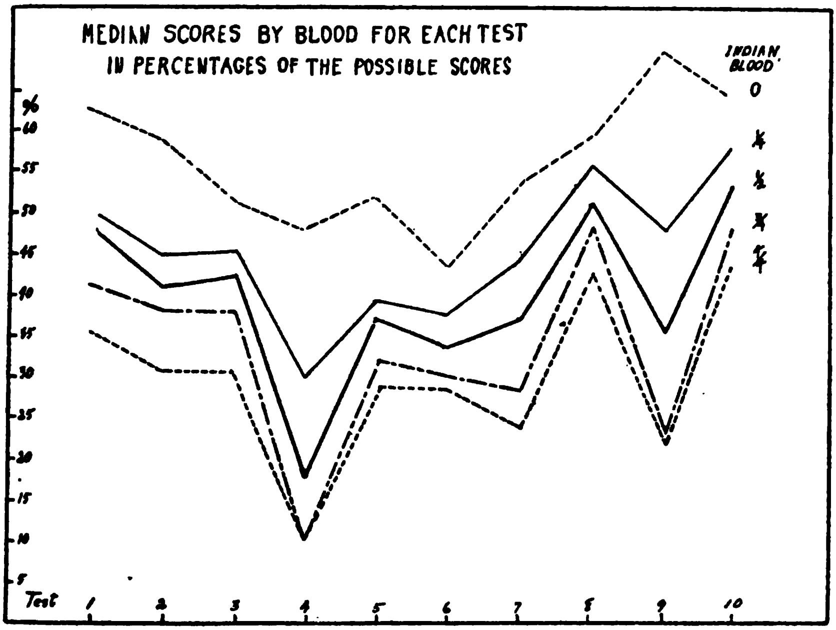


FIG. 4

So far the results presented have concerned the following problems: (*a*) the comparison of pure whites and the entire Indian group; (*b*) the comparison of pure whites and the various degrees of Indian blood; and (*c*) the comparison of degrees of blood within the Indian group itself. In each case the data employed have been either certain percentiles or else the distributions as wholes. Dr. Otis, however, has kindly furnished us with a table of age norms derived from the distribution given above in table 2. These norms make possible a comparison of the various bloods with reference to the numbers testing below, at, and above age. The norms are as follows:

AGE		NORMAL SCORE IN POINTS
Years	Months	
14	5	117
14	7	118
14	8	119
14	10	120
15		121
15	2	122
15	4	123
15	6	124
15	9	125
16	1	126
16	5	127
16	10	128
17	4	129
18		130

Quoting from Otis's letter: "This table allows for the fact that the pupils of the upper years who are in school are selected, duller pupils being dropped out of school. Intelligence is assumed to cease growth after eighteen years. Therefore the norm for all ages above 18 is taken as 130 points."

The total scores for the individual Indians of each chronological age were compared with these norms, and the percentage testing below, at, or above age for each degree of blood is given in table 6. These results are shown graphically in figure 5. The percentage falling exactly at age is small and relatively unimportant.

TABLE 6

Percentage of Indians testing below, at, or above age

BLOOD	BELOW AGE	AT AGE	ABOVE AGE
	per cent	*per cent*	*per cent*
4/4	93.2	2.2	4.6
3/4	90.9	0.7	8.4
1/2	81.6	1.0	17.4
1/4	74.3	0.0	25.7

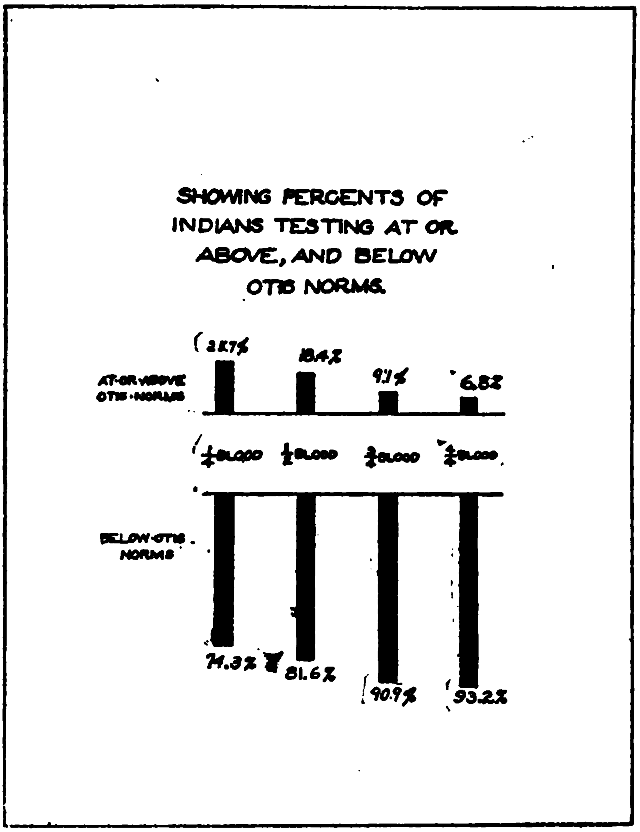


FIG. 5

This is not true of the two large classes of above and below age. Here we find a direct relation to the degree of Indian blood, the number below age decreasing and the number above age increasing with an increase in amount of white blood.

The percentages of Indians testing below the eight-year norm for white children are also interesting. Inasmuch as no subject was less than 11 years old (and only five at this age), these percentages suggest the relative numbers who had an I.Q. of 70 or less. The percentages again vary with the degree of Indian blood and are as follows:

BLOOD	PER CENT BELOW EIGHT-YEAR NORMAL
$\frac{4}{4}$	25.9
$\frac{3}{4}$	11.2
$\frac{1}{2}$	6.9
$\frac{1}{4}$	5.5

The only published report[6] on the relative intelligence of whites and Indians is that by Rowe on the Indians at Mt. Pleasant, Michigan.[7] Rowe used the Binet-Simon scale on 547 white and 268 Indian children, taking no account, however, of variations in degree of Indian blood. The percentage of Indians testing at age was 4.6 per cent, below age 94.2, and above age 1.2 per cent. These results are shown graphically with the Haskell results in figure 6. The agreement between the two investigations holds in spite of differences in the scales employed (individual vs. group) and in spite of different methods of determining mental age (point vs. age scale).

---

[6] Since this statement was written, T. R. Garth has published a study on "The results of some tests on full and mixed blood Indians" in the Journal of Applied Psychology, 1921, v, 359–372. Three hundred and eighty-four subjects composed of the two groups of pure and mixed blood were given 4 association tests, 3 memory tests, and 2 word building tests. On all 9 tests the mixed bloods made a significantly higher average performance than did the full bloods.

[7] Rowe, E. C., Five hundred forty-seven white and two hundred sixty-eight Indian children tested by the Binet-Simon tests. Ped. Sem., 1914, xxi, 454–468.

INTERPRETATIVE DATA AND COMMENTS

In seeking an explanation of the differences found between whites and Indians and between Indians of various degrees of white blood, the following factors must be considered: age, sex, social status, total months of schooling, grade in school, and a racial factor which may be either one of general intelligence or one of temperament. The possible rôle of these various factors, we shall discuss in the above order.

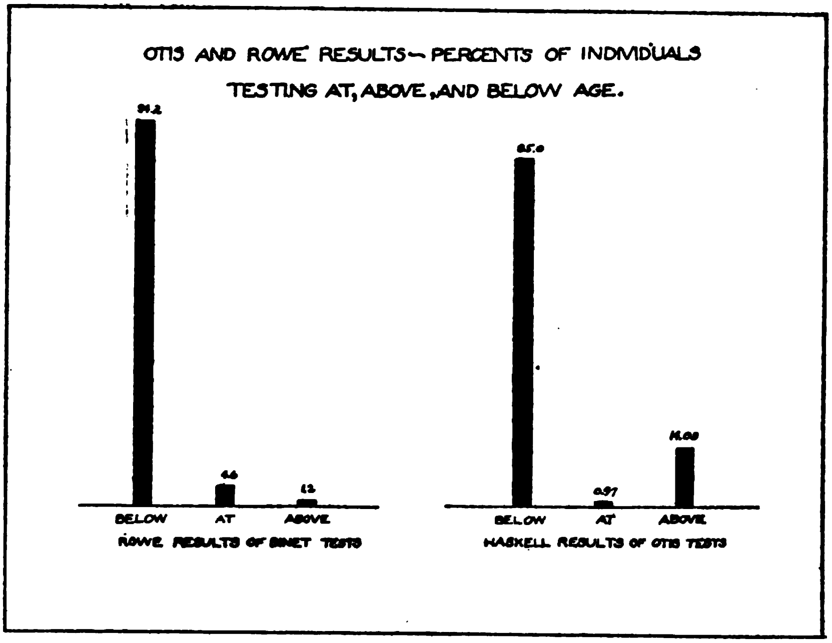


FIG. 6

1. Score on the Otis test correlates with age for the total Indian group plus 0.17±0.024. In comparing whites and Indians, age was equalized by considering the same ages (table 3). The age factor was also kept constant in the partial correlation within the Indian group. As further evidence against the adequate explanatory value of age, the following tabulation indicating no essential variation in the age distributions of the various bloods is offered:

50 per cent of 4/4 are between 16½ and 18 years 11 months
Range: 12½ years to 22½ years
50 per cent of ¾ are between 15½ and 18½ years
Range: 11 to 23 years
50 per cent of ½ are between 15½ and 18 years 11 months
Range: 11 to 21 years
50 per cent of ¼ are between 15½ and 17½ years
Range: 11½ to 20 years

2. We have no data on sex for the white subjects. Within the Indian data, it is possible that one sex was superior to the other and that the superior sex was present in increasing numbers as the degree of white blood increased in the samples used. Table 7, showing the median scores for the two sexes in the several bloods, indicates that the factor of sex does not account for the racial differences found. Although there is no consistent age difference between the sexes, the girls are slightly superior to the boys in all bloods save the one-quarter. Each sex shows a decrease in median score with a decrease in amount of white blood. This fact outweighs in importance the tendency for the slightly more intelligent sex (girls) to predominate numerically in the whiter bloods.

TABLE 7

Median scores for the two sexes

BLOOD	BOYS			GIRLS		
	Med.	σ	N	Med.	σ	N
¼	117.5	42.0	41	109.0	30.5	69
½	85.1	32.5	82	94.6	33.0	104
¾	70.1	30.25	63	86.0	33.5	82
4/4	60.8	34.06	163	71.9	35.7	99
All	71.1	36.95	349	85.1	35.7	354

3. It was impossible to secure data on social status. As indicated previously in this paper, the Indian's social environment is probably inferior to that of the white children. Within the Indian group, it is possible that social status rank decreases with increase of Indian blood. It is to be remembered also that inferior social status may well be the result of low intelligence rather than its partial cause.

4. The factor of total months in school was controlled within the Indian group by partial correlation. Table 8 gives correlations for score and months in school for the various bloods. Each blood shows a significant positive correlation, but there is no consistent increase from blood to blood as would be expected if this were a prominent causal factor in the relation of blood and score. If the relation of score and blood were being considered merely between whites and Indians, the probable later start and

TABLE 8

Correlations of score and total months of schooling

BLOOD	r	P. E.
$\frac{1}{4}$	0.276	0.059
$\frac{1}{2}$	0.38	0.041
$\frac{3}{4}$	0.42	0.045
$\frac{4}{4}$	0.32	0.037

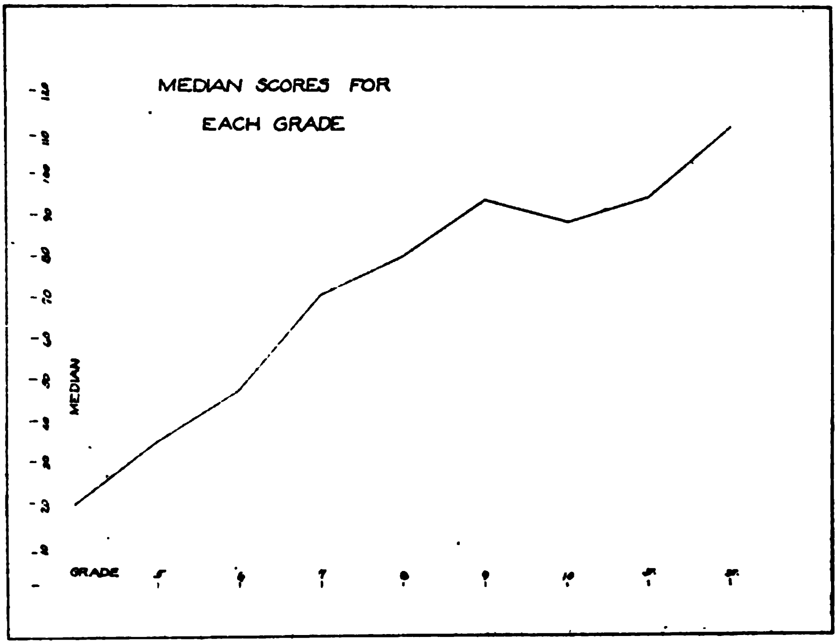


FIG. 7

more irregular attendance of the Indians would be a matter of concern. It is, however, highly improbable that such differences are constant within the Indian group itself. The range in distribution for each blood is practically the same, 11 months to 140 months, with the middle 50 per cent falling between 58 and 94 months.

5. With reference to the relation between school grade attained and degree of Indian blood, the following tabulation offers the facts:

GRADE	BLOOD			
	4/4	3/4	1/2	1/4
Unclassified	14	4	2	2
4	29	7	6	3
5	41	22	26	9
6	44	28	33	12
7	56	33	26	27
8	26	19	25	12
9	18	3	14	9
10	16	12	28	16
Jr.	10	7	13	14
Sr.	11	8	14	6
25 per cent	5th	6th	6th	7th
50 per cent	7th	7th	8th	8th
75 per cent	8th	8th	10th	10th

This indicates a slight tendency for the near-whites to be found in the higher grades. That the trend is not more evident is probably due to local conditions, such as the tendency to urge all students as far as possible through the course. However, the brighter individuals of each blood do tend to be found in the higher grades, as is indicated in figure 7 which shows the median score for each grade. It is to be remembered, to be sure, that grade attained is probably not so much a cause as a result of higher intelligence.

6. In spite of the fact that we do not know all of the behavior components entering into the determination of performance in such a situation as the Otis Scale presents, the chief explanatory

possibilities in our problem reduce to tempermental and intelligence differences due to race. By our observation of the manner in which the students worked upon the tests and by the fact that all are accustomed to school work, we are led to discredit any possible racial differences in temperament as the causal factor involved in producing the differences in score.

CONCLUSION

There is a positive correlation between increasing degree of white blood in the American Indian and score on the Otis intelligence test which would seem to indicate a racial difference, probably of intelligence although possibly of temperament.

OCT 12 1922

VOLUME II AUGUST, 1922 NUMBER 4

THE JOURNAL OF COMPARATIVE PSYCHOLOGY

Continuing Psychobiology and the
Journal of Animal Behavior

EDITED BY

KNIGHT DUNLAP
Johns Hopkins University

AND

ROBERT M. YERKES
National Research Council

IN ASSOCIATION WITH

MADISON BENTLEY
University of Illinois

HARVEY CARR
University of Chicago

WALTER B. CANNON
Harvard University

RAYMOND DODGE
Wesleyan University

SHEPHERD I. FRANZ
Government Hospital for the Insane

GILBERT V. HAMILTON
Santa Barbara Clinic,
Santa Barbara, California

SAMUEL J. HOLMES
University of California

WALTER S. HUNTER
University of Kansas

HERBERT S. JENNINGS
Johns Hopkins University

GEORGE H. PARKER
Harvard University

EDWARD L. THORNDIKE
Columbia University

MARGARET F. WASHBURN
Vassar College

JOHN B. WATSON
New York City

WILLIAM M. WHEELER
Harvard University

PUBLISHED BI-MONTHLY BY
WILLIAMS & WILKINS COMPANY
BALTIMORE, U. S. A.

Entered as second-class matter April 4, 1921, at the post office at Baltimore, Maryland, under the act of March 3, 1879

Price per volume, net postpaid
$5.00, United States, Mexico, Cuba
$5.25, Canada
$5.50, other countries

Made in United States of America

PSYCHOLOGY CLASSICS

A SERIES OF REPRINTS AND TRANSLATIONS

EDITED BY
KNIGHT DUNLAP
Johns Hopkins University

THE EMOTIONS

BY

CARL GEORG LANGE (1834–1900)
University of Copenhagen

AND

WILLIAM JAMES (1842–1910)
Harvard University

Of interest to Psychologists, Philosophers, Physiologists, and all concerned in mental life

VOLUME I

Price, net, postpaid:

$3.50, United States, Mexico, Cuba
$3.75, Canada
$4.00, Other Countries

WILLIAMS & WILKINS COMPANY
Publishers of Scientific Journals and Books
BALTIMORE, U. S. A.

THE IMMEDIATE PSYCHOLOGICAL EFFECTS OF TOBACCO SMOKING[1]

DAVID JUNE CARVER

INTRODUCTION

The work reported in this paper was done in the psychological laboratory of the Johns Hopkins University during the year 1919–1920. The reactors employed were undergraduate students in the university, with the addition of the writer and one other member of the department staff. On account of the use of students, it was impossible to control the time distribution of the reactors as thoroughly as is desirable, yet in general, the periods for each reactor were so arranged that he worked at the same hour of the day throughout, with few exceptions. Moreover, it was not possible to keep the subjects under control outside of the working hours, as should be done in ideally perfect experiments. By careful and systematic questioning, however, it was ascertained that the conditions of living and working were fairly constant, and on days when any unusual conditions of health or work had been experienced, testing was omitted.

The reactors were given specific instructions concerning the uniformization of their daily routine, and in particular, were instructed not to smoke on test days before coming up for the test. This instruction was regularly observed, except in a few cases, concerning which notes were made in the records. On intervening days, and on test days after the tests were over, "smokers" were permitted to smoke their usual amounts. "Non-smokers," of course, did not smoke at any time except in the tests in which smoking was used.

---

[1] The expenses of this research were in part defrayed by the Committee to Study the Tobacco Problem, but the responsibility for the planning and execution of the work, and for the conclusions, rests solely with the author and Professor Dunlap.

Prejudicing the reactors in regard to the tests was carefully avoided. They were informed that we had no expectation as to results, and also, that differences in results between smoking and non-smoking days, and between before-smoking and after-smoking results, might well occur on account of many factors other than the smoking. It was also made clear that neither the author nor the director of the laboratory had any views, positive or negative, as to the harmfulness of smoking.

After the total work on each reactor had been completed, he was questioned as to his own attitude toward tobacco using in general, and smoking in particular. Obviously, it would have been prejudicial theoretically, to ask the reactors before their work was finished. Most of the reactors professed to have no definite opinion on the matter, and no concern.

The experiments made bore solely on the immediate effect of smoking. The further, and important, matter of later effects: and of the effect of habituation to smoking, and of the cessation of smoking, are left for further investigation. Moreover, the results bear only on certain selected phases of the immediate mental effect, and do not purport to cover the whole ground. In general, the experiments bear on *efficiency* in certain mental operations, rather than on the details of those operations.

Eight types of test were used, namely: card-sorting; two sorts of mathematical work (addition and multiplication); the operation of an adding machine in ordinary listing; an association reaction (opposites); dart throwing; the steadiness test; and billiard playing. These tests are described in detail, with the results, below.

In order to obtain measurements with and without tobacco effects (if any), two procedures were adopted. In the *alternate day* procedure, the reactors were required on one day to smoke before taking the tests, on the next day to take the test without smoking, and so on alternately. In the *before and after* procedure, the experimental hour was divided into two work periods, with a "smoking" or "resting" period between. One one day the reactor smoked during the interval; on the next day he rested without smoking. These two procedures were used as a check on each other.

The amount of smoking in each test was not thoroughly standardized. Each reactor smoked either one cigar, or three cigarettes during each smoking test. The cigarettes were of a well known brand; the cigar a standard Key West, Colorado-Claro of medium weight. Cigars were smoked down to one-quarter or less; cigarettes to stubs.

While we had planned more definite standardization, we found that fine control of the tobacco itself would be meaningless. Smokers vary so much in the relative time of holding smoke in the mouth, and the depth to which it is taken in the mouth, throat, and lungs, that a mere standardization of the weight of leaf consumed would give only a misleading appearance of accuracy.

I. TESTS OF SPEED AND ACCURACY

1. *Card sorting*

The primary material for this test,[2] as devised by Dr. Dunlap, consisted of two packages of standard sized playing cards, each of which was punched centrally with a diamond shaped hole, the diameters of which were 2.5 cm. and 1.2 cm. respectively. These cards were punched in four ways, viz.: with the long diameter of the diamond (1) in the long diameter of the card, (2) in the short diameter of the card, (3) diagonally, from upper right to lower left, (4) diagonally, from upper left to lower right. One quarter of the cards were punched in each of these ways, and the cards were always faced the same way, in order to keep the two diagonally punched cards equal in number.

In conjunction with these cards, a receptacle consisting of a row of five stalls, was used. The cards, thoroughly shuffled by a standardized routine, were placed in the stall at the extreme left, and the reactor was required to take the cards off the stack one at a time with the left hand: then, still holding the card with the left hand, to "feel" the hole with the finger of the right hand, and after identifying it, to place it with the right hand in the proper one of the four remaining stalls.

---

[2] Johnson, B. Jour. Compar. Psychol., 1922, ii, 163.

The receptacle was fastened on a small table in a standardized position with regard to the reactor. A rectangular adjustable screen was so placed that the reactor could not see his hands or the cards at any time, but could see the tops of the backs of the stalls and the indicators (sample cards) fastened to each of the four stalls in which cards were to be placed. The screen allowed the reactor perfect freedom in manipulating the cards, but compelled him to sort the cards by "feeling."

The advantages in this form of discrimination test lie in the avoidance of eye-strain and other purely visual difficulties. So far as correlation of fatigue and attention is concerned, the test is at least as satisfactory as a visual sorting test under the best condition of vision.

In the "alternate day" procedure, each reactor (except reactor VI) sorted the cards five times each day, working on a ten-minute "headway." That is: the "hour" (fifty minutes) was divided into five ten-minute periods. At the beginning of each period, the cards being in readiness in the left stall, the reactor began to sort the cards. His time was taken with a stop watch from the beginning to the placing of the last card, and following this the errors were recorded, the cards reshuffled and placed in position for the next sorting, and the subject rested. Reactor VI followed the same general procedure, but sorted the cards seven times on each day.

In the "before and after" plan, the hour was divided into three "before" periods of eight minutes each: a "smoking" or "resting" period of twelve minutes, and three eight-minute "after" periods. In other words, the reactor sorted three times on an eight minute headway before smoking (or resting) and three times afterwards, on the same headway.

In all of the tables which follow, *t.* following the reactor's number indicates habitual cigarette smoker, *r.* habitual cigar smoker, *p.* habitual pipe smoker, and *n.* indicates non-smoker. Where a reactor, not a habitual cigar smoker, smoked a cigar in the test, this is indicated by (*r.*), and smoking of cigarettes in the test by a reactor not a habitual cigarette smoker, is indicated by (*t.*).

The results of the card sorting test seem to show that errors in the discrimination are increased after smoking. Every reactors, except one, in the alternate-day test, made more errors on the smoking than on the non-smoking days. In the before-and-after test, reactors I, II, III, VI and X made the same, or fewer errors after resting than before resting, but made more errors after smoking than before smoking. But IV, V, VIII and IX, while making more errors after smoking, also made more after

TABLE 1

Card sorting: Alternate days

REACTOR	DAYS	NON-SMOKING		SMOKING	
		Time	Error	Time	Error
I *t.*	4–4	2′ 28″	1.25	2′ 34″	1.3
II *r.*	3–3	2′ 15″	1.00	1′ 57″	1.46
III *t.*	3–4	2′ 41″	0.73	2′ 30″	1.35
IV *n.* (*t.*)	5–5	2′ 42″	0.84	2′ 38″	0.84
V *n.* (*t.*)	6–6	3′ 28″	0.3	3′ 53″	0.43
VI *t.*	3–3	3′ 21″	0.52	3′ 09″	1.18

TABLE 2

Card sorting: Before and after

REACTOR	DAYS	RESTING				SMOKING			
		Before		After		Before		After	
		Average	Error	Average	Error	Average	Error	Average	Error
I *t.*	3–3	2′ 01″	0.22	2′ 02″	0.22	2′ 07″	0.11	2′ 06″	0.77
II *r.*	3–3	1′ 39″	0.88	1′ 39″	0.66	1′ 41″	0.83	1′ 40″	0.92
III *n.*(*t.*)	4–3	3′ 04″	0.33	3′ 03″	0.0	3′ 02″	0.11	3′ 06″	0.22
IV *n.*(*r.*)	5–4	4′ 07″	0.93	3′ 52″	1.4	3′ 54″	1.41	3′ 49″	2.41
V *t.*	3–3	3′ 38″	.0	3′ 34″	0.33	3′ 35″	0.11	3′ 36″	0.55
VI *r.*	3–3	3′ 27″	5.0	3′ 30″	4.55	3′ 31″	5.77	3′ 15″	7.33
VII *t.*	3–3	4′ 37″	0.22	4′ 31″	0.44	4′ 26″	0.0	4′ 07″	0.0
VIII *t.*	4–4	2′ 10″	1.25	2′ 07″	1.66	2′ 05″	1.16	1′ 57″	1.83
IX *n.*(*r.*)	3–3	3′ 29″	0.88	3′ 28″	2.22	3′ 34″	0.55	3′ 43″	1.66
X *n.*(*r.*)	5–4	4′ 19″	1.46	4′ 16″	1.46	4′ 25″	1.08	4′ 19″	1.5
XI *t.*	5–5	4′ 44″	3.74	4′ 21″	3.06	3′ 59″	3.2	3′ 55″	2.46
XII *r.*	4–4	2′ 13″	0.41	2′ 12″	1.33	2′ 14″	0.41	2′ 15″	0.33
		3′ 17″		3′ 12″		3″ 12′		3′ 09″	

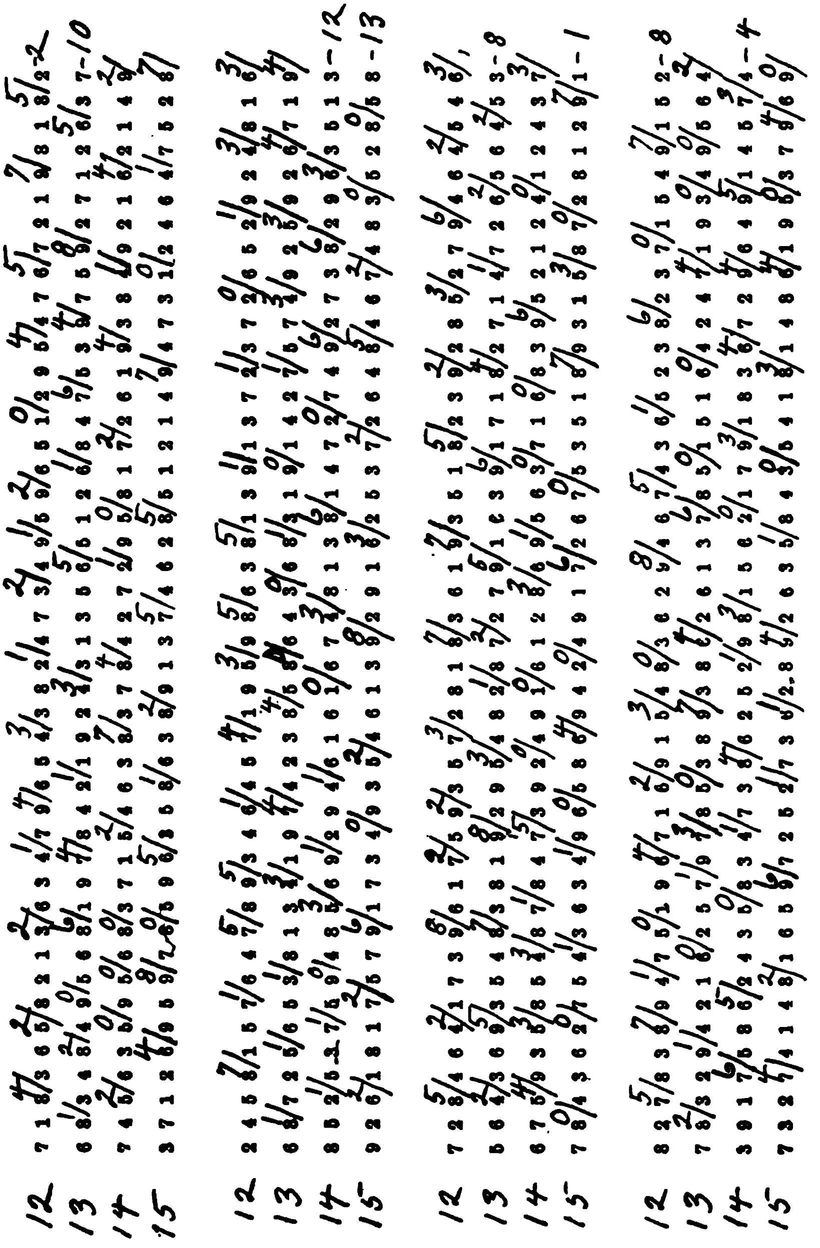
resting. Reactors VII and XII made more errors after resting, fewer or the same after smoking, while reactor XI made fewer after both resting and smoking. A comparison of the after-smoking with after-resting errors, shows no consistent variation, and no greater variation than is shown by the comparison of the before-smoking and before-resting errors.

A study of the distribution of errors within the working period, and of the variations in the sorting times through the periods, shows no systematic or uniform effect of the smoking.

On the whole, therefore, the only conclusions from these tests are (1) that there may be a slight tendency, in the case of some subjects, to increase error in discrimination after smoking, but that tests of the character of card sorting are not competent to show this clearly. (2) That if there are any effects of smoking on the speed of the discriminating reaction, tests of this character are not competent to show them. We would suspect any results of similar tests, purporting to show either favorable or unfavorable effects of smoking, to be due to faults of experimental technique, or to the employment of exceptional subjects. We consider it quite probable that, with less careful control of suggestion, and of other matters of technique, either type of result might have been obtained in these experiments. The results of these experiments showed that it was useless to continue this test. It is true that the tests as given cover the practice period, or period in the reactor's work within which improvement in speed was being made. There is, however, nothing in the detailed data to warrant the conclusion that definite effects can be discovered by the test, after the learning period is over, and the sorting process well mechanized; and we do not consider it worth while to undertake longer series on this particular test.

2. Addition test

The material used in this series of tests was the two forms of the Dunlap number work test, each consisting of a sheet containing 16 lines of 45 digits each, so arranged that each of the 9 digits (excluding zero) appeared five times in each line. At the left



ADDITION TEST. SAMPLE SHEET

of each line appeared a key-number, and the subject added digits till he obtained an amount equal to or greater than that key-number, drew a line after the last digit used and wrote above the line the difference, if the last digit used gave a sum greater than the required number. In our test the four key numbers, 12, 13, 14, 15 were used and were cyclically changed in successive sheets. On the first sheet the order was 12, 13, 14, 15, for each of the four-line groups. On the second sheet the order was 13, 14, 15, 12; on the third, 14, 15, 12, 13; and on the fourth, 15, 12, 13, 14. Two forms of this test sheet were available, making a total of 8 sheets of approximately equal difficulty, which could be used without repeating any key number with the same line. The sheets were not repeated with sufficient frequency to allow of memory from one trial to another.

TABLE 3

Addition test

REACTOR	DAYS	RESTING				SMOKING			
		Before		After		Before		After	
		Time	Error	Time	Error	Time	Error	Time	Error
I *n*.(*r*.)	4–4	9′ 53″	3.25	9′ 46″	3.25	9′ 10″	2.75	9′ 42″	5.25
II *r*.	7–7	9′ 54″	6.0	9′ 51″	3.42	9′ 18″	3.42	9′ 16″	5.0
III (*t*.)	4–4	9′ 00″	2.75	8′ 42″	2.0	8′ 57″	3.0	8′ 28″	5.75
IV *p*.(*r*.)	3–3	9′ 21″	5.33	9′ 10″	5.33	9′ 27″	3.66	9′ 03″	4.66
V *t*.	5–5	9′ 41″	1.0	9′ 50″	2.0	9′ 52″	1.8	9′ 43″	2.2
VI *n*.(*t*.)	3–3	13′ 43″	0.66	13′ 43″	2.66	15′ 14″	2.66	14′ 59″	1.66
VII *t*.	4–4	18′ 32″	2.5	18′ 48″	2.0	17′ 01″	2.75	16′ 34″	5.25
VIII *n*.(*r*.)	6–6	9′ 48″	3.5	10′ 01″	5.16	9′ 12″	5.16	9′ 28″	7.33

Eight subjects went through this test on the before-and-after plan, working one complete sheet before, and one after smoking, or resting, on alternate days. The time required for each sheet was recorded by a stop watch.

In a smoking period, the subject smoked three cigarettes or three-fourths of a cigar, beginning the smoking as soon as he finished the first sheet. The following tables give the individual results.

The results of the addition test are given in table 3. Each of the reactors, except VII, was allowed one to three practice days, according to the difficulty encountered, in order to become familiar with the method of addition prescribed. VII had worked several of the sheets previously in another test.

The results of the addition test, like those of the card-sorting, were not indicative of a definite effect of smoking on speed. Reactors II, III, IV, showed a decrease in time both after resting and after smoking. V, VI, and VII showed the same, or an increased time after resting, and decreased time after smoking. I and VIII showed increase both after smoking and after resting. The evidence for increase in error was, however, fairly clear. In every case, except one, there was an increase in the number errors after smoking; all except three, showed the same number, or a decrease, after resting.

3. Multiplication test

The material for this test consisted of 8 sheets, each sheet containing 16 multipliers and 16 multiplicands, arranged in two parallel columns, as in the sample sheet. The reactors were required to multiply each multiplicand by the multiplier opposite it, not copying these, but writing down in each case the three partial products, and adding them, on the sheet. After working one sheet, the reactor smoked three cigarettes and then worked a second sheet.

List 6

Multiplicands	Multipliers
771	736
435	531
914	238
566	577
187	125
146	469
295	624
359	881
194	431
554	893
986	492
823	857
973	672
732	468
123	173
246	889

Multiplication material. Sample sheet

Each of the eleven reactors worked on eight days, working one "before" and one "after" sheet each day. Six of the subjects began with sheet 1 before smoking, sheet 2 after smoking, and on the the next three days took sheets 3, 5, and 7 before smoking, and 4, 6, and 8 after smoking. The other five reactors began with sheet 2 before smoking, sheet 1 after, taking 4, 6, and 8 before, and 3, 5, and 7 after, the following three days. During the next four days the order was inverted, the first group working the even numbered sheets before smoking; the second group the odd numbered sheets before smoking. In this way each reactor worked each of the pairs both ways, and the effects of possible difference or difficulty between the sheets in a pair were neutralized.

After finishing the eight smoking days, 8 of the subjects worked four more days, resting, instead of smoking, between the sheets of the pairs. The order of sheets in this case was the same as in the "first round" for the same subject.

The results of the smoking sets are given in table 4. Reactors I to VI began with sheet 1 in the first round, with sheet 2 in the second round, while reactors VII to XI began with sheet 2 in the first round, with sheet 1 in the second.

The general results of practice are obvious, when the second round is compared with the first; although reactors V and X retrograded, the others improved. The usual increase in error after smoking is shown: the average error per sheet in the first round is 2.45 per sheet before smoking, and 3.43 after smoking, and in the second round 2.59 before smoking, and 2.97 after. The average errors for eight subjects before and after resting (not smoking), as shown by table 5, are 2.15 before resting and 1.96 after resting. If we eliminate from table 4 the three reactors (I, IV, and V) who do not appear in table 5, an increase in error is still shown after the smoking period. But still more important is the fact that nine of the eleven subjects show the after-smoking increase in error in the first round, and seven in the second; whereas only two of the eight in the non-smoking set shown an increase after resting.

TABLE 4

Multiplication test

REACTORS	BEFORE SMOKING		AFTER SMOKING	
	Time	Error	Time	Error
First round				
I	7′ 06″	5.25	6′ 06″	5.75
II	7′ 01″	0.25	7′ 01″	0.75
III	7′ 32″	1.25	7′ 37″	1.50
IV	6′ 41″	1.75	6′ 10″	3.50
V	8′ 14″	3.75	8′ 40″	7.50
VI	7′ 37″	2.25	7′ 29″	2.50
VII	7′ 08″	2.5	7′ 01″	5.25
VIII	7′ 47″	2.25	8′ 25″	2.8
IX	7′ 16″	2.5	7′ 05″	2.25
X	7′ 10″	2.0	7′ 18″	1.0
XI	6′ 68″	3.25	6′ 14″	5.0
Second round				
I	6′ 23″	6.25	5′ 46″	5.25
II	5′ 31″	0.25	5′ 18″	0.50
III	5′ 58″	2.50	6′ 00″	1.75
IV	6′ 36″	2.50	6′ 35″	3.00
V	8′ 06″	2.75	7′ 56″	5.00
VI	7′ 24″	1.25	7′ 13″	2.00
VII	5′ 56″	3.25	6′ 06″	3.25
VIII	6′ 51″	2.75	7′ 11″	4.50
IX	5′ 55″	1.25	6′ 17″	1.25
X	7′ 17″	1.50	7′ 32″	2.25
XI	5′ 55″	4.25	5′ 34″	4.00

TABLE 5

Multiplication test

Without smoking

	TIME	ERROR	TIME	ERROR
II	5′ 23″	2.5	5′ 19″	1.25
III	6′ 24″	1.0	6′ 27″	0.75
VI	7′ 03″	0.25	6′ 57″	1.50
VII	5′ 46″	4.25	5′ 57″	2.75
VIII	6′ 24″	2.25	6′ 18″	3.0
IX	5′ 39″	2.50	5′ 32″	2.50
X	6′ 44″	2.25	6′ 37″	1.75
XI	6′ 02″	2.25	6′ 05″	2.25

As for the effect on speed, the indications are less clear. Six of the eleven reactors show an increased speed after smoking in the first round, four show decreased speed, and one shows no change. In the second round, six show increased speed, and four show decreased, although in one case the gain is only one second, and in another the loss is only two seconds. Two who gained in the first round lost in the second, and one who lost in the first round gained in the second.

4. *Adding machine test*

The card-sorting, addition, and multiplication tests required the reactors to aim at speed, and also at accuracy of rather complicated coördinated reactions, failure in details of which might lead to error. It is highly desirable to use also tests in which the reactions may be made more mechanical, requiring less careful discrimination on the one hand, and less precise adjustment of action on the other. The operation of the Burroughs Adding Machine in plain listing seems to offer possibilities of such a test; and in order to try this out, two reactors who had already acquired facility in operating the machine were put at work on the before-and-after plan. Both reactors were "occasional smokers," and both smoked cigars in this test.

The Burroughs was electrically driven, so that no labor other than pressing buttons was required. The material to be added consisted of the Johns Hopkins four place addition sheets,[3] ninety sheets of which, each sheet containing merely four place numbers, all sheets of equal difficulty, have been worked out.

The sheets were arranged with the ninety numbers in a single column, separated by spaces into six groups of fifteen numbers each. The reactor was required to subtotal each group, and total the whole. The sub-totaling provides a rapid method of checking for error. Time was taken for the whole sheet.

In this test, reactor I worked three sheets before smoking or resting, and three after. Reactor II worked two sheets before and after. Smoking and non-smoking days alternated as usual.

---

[3] Norcross, W. H. Jour. Compar. Psychol. 1921, i. 321.

Reactor I worked nine days, five smoking and four non-smoking. His average time for a sheet on the smoking days was 4′ 22″ before smoking, 4′ 18″ after smoking. On the non-smoking days his times were 4′ 22″ before resting and 4′ 20″ after resting.

Reactor II, on five smoking and four non-smoking days, worked only two sheets before and after smoking or resting. His average times were 3′ 41″ before smoking and 3′ 36″ after: and 3′ 38″ before resting and 3′ 33″ after. Nothing was shown by these tests concerning tobacco effects on speed, and the results were so uniform that we did not think it useful to continue further with those subjects. The test is, however, worth trying on a larger scale, with subjects who have had no previous training on the machine, so that the effects (if any) of tobacco in the learning period could be compared with those in the later period when the process has become more nearly automatic.

The error in the listing of the numbers averaged, per sheet: for reactor I, 1.66 and 1.83 before and after smoking, and 0.75 and 1.25 before and after resting; for reactor II, 1.08 and 0.66 before and after smoking, and 0.75 and 0.59 before and after resting. In that case, then, the tendency towards increase of error, after smoking, shown in the previously described tests, does not occur. This is an important point, which is quite compatible with the difference between the adjustments required in this test and the card-sorting, multiplication, and addition tests, if we assume that the primary mental effects of smoking are a lessening of the integrative action of the neurons.

The adding machine test, it is obvious, should be carried out on a large scale, for comparison with other tests. The other work of the present survey precluded entering upon this phase of the work on a scale large enough to be useful, hence it was laid over for the time being.

5. *Association tests*

An important part of our plan included the attempt to find the influence, if any, of smoking upon the "association of ideas." This work, of course, must cover many phases, including the formation, as well as the "reproduction," of associations. As a point of departure, we took up the problem of *controlled associative recall* with seventeen reactors, using the Dunlap chronoscope and voice keys for measurement of the reaction times.

The type of reaction control was that of *opposites*. Six lists of twenty words each were used, and in each case the reactor was required to reply with the "opposite" of the stimulus word, i.e., the word of directly contrary meaning. The word-lists were prepared, very carefully, from the Loring word lists,[4] in an attempt to obtain lists of equal difficulty. The results show, however, that we did not succeed.

Each of the seventeen reactors worked three days, all three being "smoking" days, on which the subject was given one list of words before and one after smoking. Non-smoking days were not used, because it was not considered advisable, at the start, to attempt the construction of more than six word-lists.

Eight of the reactors were given word-lists A, C, and E before smoking, and lists D, E, and F after smoking; and the remaining nine reactors were given the lists in the reverse order, that is, D, E, and F before smoking, and A, C, and E after.

After completing the set of tests on the seventeen reactors as outlined, four were again put through the series, with the same word lists, but in reverse order, so that in the second set, the reactor had, after smoking, the lists he had been given before smoking in the first round, and vice-versa.

Obviously, we had no formal basis for comparison in our results, except on the minor point of the comparative difficulty of the word lists. A change in the speed of recall after smoking *might* be assumed to be due to tobacco effects, or to the mere temporal sequence of the two lists, except in so far as our previous acquaintance with association-reaction practice and fatigue effects might enable us to decide: there are no criteria in these particular results taken by themselves. Hence, although the results were most interesting, we prefer not to present them at present, as they are not necessarily cogent to other than the experimenters.

---

[4] Loring, M. W. Psychobiol., 1918, i, 429–444.

We can say the following, however:

1. The word lists were not of equal difficulty, in spite of the labor spent upon them, and the most severe difficulty in the way of the further prosecution of this problem is the difficulty of constructing a sufficient number of lists of equal difficulty. To construct twelve such lists of opposites would be in itself a large job, requiring an extensive program of experimental work.
2. In spite of the difficulty of the task, the investigation of the controlled associative reaction, if it can be carried out, promises to give definite and important results, which should be compared with results of free-association tests and learning tests. We do not consider the time and energy spent in the carrying out of these preliminary tests, and in the preparation of the material, as wasted.
3. Casual tests of association are of no value whatever. Work will be entirely wasted (perhaps the results gravely misleading) unless done on an elaborate scale of materials, reactors, and technique. We should not expect a competent investigator, working on this problem alone full time with clerical assistance, to obtain any result which might be given out as other than "tentative" in less than two years.

II. TESTS OF ACCURACY ONLY

In the group of tests just described, both time and accuracy were measured, and the reactors were attempting to be both quick and accurate. In the results of those tests no effect of tobacco on speed is indicated, but an effect on accuracy is apparent. While the accuracy score would have no significance in those tests unless the reactors were working against time, the effort at speed might well have an influence on the errors. The next group of tests was designed to test accuracy only, there being no element of speed involved.

6. *Dart throwing*

In this test, which is modified from the Buford Johnson dart test,[5] the reactors threw the small feathered darts (made by the

---

[5] Johnson, B. Psychol. Rev., 1919, xxvi, 302–303.

Apex Dart Company), attempting to hit the bull's-eye of a target. The targets, which were blue-prints, had white bull's-eyes 1½ inches in diameter, on a dark-blue ground, and five concentric narrow white rings of 6, 12, 18, 29, and 30 inches in diameter. The targets were pasted on a veritcal backing of heavy cork, 15 feet from the reactors' "toe-line" from which he threw, with the bull's-eye at approximately the level of the reactor's shoulder.

Each reactor, on each working day threw five sets of 25 darts each before smoking or resting, and five sets after smoking or resting. The darts were thrown with such rapidity of sequence as the reactor chose, with a five minute headway of the sets. That is: the throwing of the second set of 25 was commenced five minutes after the commencing of the first set; the third set was commenced five minutes after the commencing of the second set, and so on. In that way, the 125 darts before smoking and the 125 after, were in each case distributed in five groups through a little over twenty minutes, and yet the reactors threw without being hurried or retarded.

The reactors "smoked" and "rested" (without smoking) for the usual twelve minutes on alternate days between the first five sets and the second five, consuming a cigar, or three cigarettes, as indicated for each subject.

In scoring each set, a dart in the bull's-eye was scored 5, in the first ring 4, second ring 3, third ring 2, fourth ring 1, and in the fifth ring or beyond, 0. Since all darts were allowed to remain in the target until 25 had been thrown, the maximum score possible is not much over a hundred, since only three or four darts could occupy the small bull's-eye simultaneously. At the fifteen-foot throwing distance, this limit was never reached: the number of darts reaching the bull's-eye never filled it.

All of the reactors had had from two to eighteen days previous practice in dart throwing, in previous work, as indicated in the table. The results are given in table 6, in which each value is the average of five scores per day, for the indicated number of days. For reactor I, for example, the before and after scores are averages for six days, a total of 30 sets, or 750 darts before smoking and the same number after smoking: and 30 sets also before and after "resting" on the non-smoking days: a total therefore, for the reactor of 3000 throws for the test.

The results of the dart throwing indicate that in spite of individual differences, cigar or cigarette smoking decreases accuracy. The general tendency is towards increased scores in the second sets without smoking, but towards less increase, or decrease, in the scores of the second sets after smoking. Obviously, the results are not conclusive; the variation in the initial sets (before smoking and before resting) are significant of uncontrollable variations in general condition of the reactors.

TABLE 6

Dart throwing

REACTOR	DAYS	SMOKING		RESTING		PREVIOUS PRACTICE
		Before	After	Before	After	
I *n.(r.)*	6–6	73.4	72.3	71.4	73.8 cigar	(2)
II *t.*	3–3	68.1	71.0	67.9	63.6 ct.	(10)
III *t.*	3–3	73.9	75.0	69.9	76.8 ct.	(15)
IV *n.(t)*	3–3	76.4	68.8	75.3	76.5 ct.	(13)
V *r.*	3–3	67.5	70.8	62.8	66.8 cigar	(15)
VI *t.*	3–3	77.9	76.2	73.4	77.9 ct.	(21)
VII *t.*	5–5	74.7	73.8	74.6	74.6 ct.	(3)
VIII *t.*	3–3	64.9	54.2	59.8	61.7 ct.	(18)

But the results are nevertheless sufficiently clear to enable us to say that the test is an entirely competent one, and to predict that more elaborate application of the test will show that small, but definite lowering of scores by smoking, in the case of the majority of individuals, indicates a general lowering of voluntary coördination of movements. "Individual differences," so characteristic of tobacco effects, will of course be found.

7. *The steadiness test*

In this test we used Dunlap's steadiness apparatus,[6] which consists of two 6-inch metal disks mounted in such a way as to be adjustable for height and angle. The front disk has eleven holes around the circumference, graduated from $\frac{1}{8}$ to $\frac{3}{8}$ inch in diameter. The back disk had a single hole the size of the largest on the front disk. In giving a test the disks were adjusted so that the center was at the height of the reactor's shoulder. The angle of inclination was kept constant in these tests. By leaving the back disk stationary and turning the front one so as to bring any desired hole over the hole of the back disk, the position remained identical throughout the several trials. A metal stylus $\frac{1}{64}$ inch in diameter was held in the hole, and contacts between the stylus and the side were recorded by the experimenter, who listened to a telephone connected in series with disc, stylus, rheostat, and the 120 volt D.C. power circuit. When used in this way, the telephone is extremely sensitive to contacts between stylus and plate.

---

[6] Dunlap, K. Jour. Exper. Psychol. 1921, iv, p. 430–432.

In our tests the reactor held the stylus in each of three holes in succession for twenty seconds with twenty seconds intervening rest. This constituted a "trial." The trials were given on a seven-minute head-way, the reactor resting or smoking during the time not consumed by the test.

The time of each trial was approximately two and a half minutes, since the twenty seconds during which the reactor held the stylus in the hole was not timed from the insertion of the stylus, but from the moment when the reactor first got it in the proper position within the hole, free from the sides. A few seconds were thus lost at each insertion. Seven minutes head-way, therefore, gave an interval of approximately four and a half minutes between the end of one trial and the beginning of the next.

After the third trial each day, the subject began smoking, and continued except during the actual trials, until three cigarettes of three-fourths of a cigar, had been consumed. The rate of smoking was rapid and variable, and the smoking ended sometimes just before the fourth, sometimes just before the fifth trial (4½ to 10 minutes).

From seven to twelve trials were made daily by each reactor. On the first three days, holes of 12, 11 and 10 sixty-fourths of an inch were used with all reactors. Certain of the reactors were next put on holes 10, 9, and 8, but others were too inaccurate to put on these.

The instructions given each reactor were as follows:

I. Stand straight; left hand on hip.
II. Before inserting, ventilate lungs thoroughly.
III. After inserting, breathe abominally only. (Chest movements disturb arm position.)
IV. Keep eyes fixed on hole: but keep maximal attention on feelings in joints and muscles of arm.
V. Touches made while inserting or withdrawing the rod are not to be counted.

TABLE 7

Steadiness test

REACTOR	DAYS	1	2	3	4	5	6	7	8	9	10	11	12
Holes 12, 11, 10													
I *t.*	3	88	75	78	69	48	72	100					
II *t.*	2	124	128	169	206	147	172	141	134	98			
III *t.*	3	16	18	14	10	21	37	59	44	36	29	11	
IV *t.*	2	1	0	1	0	1	1	1	0	1			
V *t.*	3	17	9	11	8	14	9	9					
VI *t.*	4	2	3	0	1	5	1	1	2	0			
VII *r.*	3	13	6	6	6	4	2	6	4	4			
VIII *n.* (*t.*)	2	10	4	5	7	1	3	5	4	3	0	1	
XI *n.* (*t.*)	3	22	19	11	17	45	48	78	56	34	35	21	10
Holes 10, 9, 8													
	1	6	7	8	11	30	34	44					
VI	5	15	7	7	14	3	17	12	6				
VII	6	8	5	9	3	7	11	14	17	9	2		
VIII	6	37	51	32	40	37	32	30	31	14	7		
IX	4	58	56	62	60	91	137	184	188	62	58		

The results of the steadiness tests are summarized in table 7. The number entered for any reactor under a given trial is the total number of touches made in all three holes on that trial on the days indicated. For example: reactor I worked three days on the holes 12, 11, 10, making seven trials on each of the three days. The total number of touches on the first trials of the three days, was 88 (an average of 29.3 for the first trial of each day).

The first trials in most cases show higher values than do subsequent trials. These are adjustment-effects which are characteristic of the steadiness test, hence the first trials should be neglected. The second and third trials give a fair estimate of the reactor's coördination before smoking. Since smoking began upon the completion of the third trial, we might reasonably look for effects of smoking (if any), at any time thereafter.

Reactors I, II, IV, VII and VIII show no clear effects in holes 12, 11, 10. Reactors III, V, VI and IX, however, do apparently show a tendency to decreased control, beginning on the first or second trial after smoking was begun. In holes 10, 9, 8, reactors V, VI, and IX again show the same tendency, while reactors VII and VIII again fail to show it. The effects may be accidental variation in some cases, but certainly are not in the 10, 9, 8 cases. It is interesting to note that one of the "non-smokers" (IX) shows the effects, but the other (VIII) does not. It can safely be said that some reactors show a tendency to decreased "steadiness" of hand (decrease in hand and eye coördination) as a result of smoking; and that there are individual variations in the restoration of the coördination.

This test was purposely made in the rough form in which steadiness tests have so often been employed. We wished to see what a rough test, under carefully controlled conditions, would show, when extended for several days. The steadiness test needs much more refined technique than is generally employed, and it is clear that a prolonged investigation with such technique will show large individual differences in tobacco effects. The effects on the different types of movement involved in unsteadiness (tremor, slow oscillations, and perhaps other types), need to be investigated in order to make this work significant. Furthermore, the effect of conditions of fatigue, attention, and emotion need to be studied in connection with steadiness, and the variations in steadiness correlated with variations in accuracy of active movement; for it is accuracy of active movement which is practically important, rather than ability to maintain a fixed attitude.

8. *Billiard tests*

Because of the complexity of the processes, and the nice adjustment required, in billiard shots, and the ease with which they may be measured, it is apparent that billiards offer exceptional opportunities to study not only learning processes, but also effects of drugs and of fatigue on the accuracy of conscious reactions. We so far have made a mere beginning in applying the billiard technique to the tobacco problem, but the results have been most encouraging. Three reactors only were employed; I, the author; II, a teacher (male) of 55; III, an undergraduate. Reactors II and III had had practice in various shots on the table during the two weeks preceding the beginning of these tests.

Three standardized "set-ups" devised by J. N. Hauser, were made the basis of the tests, using ivory balls on a standard 4½ by 9 table. These three set-ups were technically (a) a draw, (b) a follow, and (c) a dead ball shot. The reactor was required to try to make the point, and also to gather the balls as near as possible to the red ball, which was always set up as the second object ball.

The reactor was required to make ten shots on the (a) set-up; then ten on the (b), and ten on the (c). This constituted a "round." The maximal score on each shot was six; the maximal on a round therefore was 180. The balls were accurately spotted before each shot, and the "gather" was measured after the shot with a ruler. The reactor was allowed to adopt whatever rate of speed in playing suited him.

For the first set of tests, the alternate day plan was used for 12 days with all three reactors. On the "smoking" day, reactors I and II smoked each a cigar, reactor III, 3 cigarettes, before playing. In the alternate days reactors I and II did not smoke at all; and reactor III did not smoke on those days until after the billiard test. Each reactor played three rounds (90 shots) on each day of this test. The results are given in Table 8. The figures under (a), (b) and (c) in this table are averages of the daily total scores on each of the three set-ups.

After finishing the first set of the billiard shots, reactors II and III worked further for 14 and 12 days respectively on the before-and-after plan, shooting two rounds of the three set-ups before smoking, and two rounds after smoking on half of the days; and two rounds before and after resting without smoking on the other days; the smoking and non-smoking days being alternated. The average scores for a round for reactor II were: before smoking, 138.2; after smoking, 136.2; before resting, 136; after resting, 143.3. For reactor III, the scores were: before smoking, 124.2; after smoking, 128.7; before resting, 125; after resting, 125.4.

While all three reactors made better scores on the non-smoking days of the alternate day plan, the habitual smoker (III) made better scores after smoking on the before-and-after plan, but practically identical scores before and after resting; and the non-smoker (II) made better scores after resting, but poorer after smoking. This might appear to indicate a differential effect due to habituation, the non-smoker being deleteriously affected by the tobacco products to which his system was not adapted, while the smoker, lacking his customary smoking stimulation in the before-smoking series, was restored to his normal condition by the smoking. This hypothesis is still further suggested by the consistency of the daily averages, and the fact that for reactor III, the elimination of the first four days' scores, which are considerably lower than the scores for the remaining eight days, increases the difference between the smoking and resting scores, the scores after resting being actually lower than before resting on these days.

TABLE 8

Billiard shots: Alternate days

REACTOR	DAYS	SMOKING				NON-SMOKING			
		(a)	(b)	(c)	Total	(a)	(b)	(c)	Total
I *n.* (*r.*)	7–7	98.4	103.8	109.1	311.4	99.4	109.8	105.5	314.8
II *n.* (*r.*)	6–6	102.5	104.5	111.3	319.1	105.0	127.5	115.3	330.8
III *t.*	6–6	116.6	119.3	119.6	355.6	122.5	124.0	121.8	363.3

The uniform alternate-day effect together with certain indications from other tests, suggests that in the case of an habitual smoker, tobacco may have effect on the learning process which it does not have, or has to less extent, on the reactions after they are fairly well learned. Of course, these few tests are competent merely to raise problems and indicate possible directions and methods of research.

GENERAL SUMMARY

1. The experimental work above reported covered a large amount of ground, and was carried on with strict regard for the conditions included in the method. The work was of the exploratory character which is the essential preliminary to more detailed investigation. On account of the nature of the work, the results are given no statistical treatment, since the calculation even of probable error in such data gives only a fictitious appearance of reliability. Certain results of value are, however, deducible.

2. It is strongly indicated that the immediate effect of smoking, both on smokers and non-smokers, is a lowering of the accuracy of finely coördinated reactions (including associative thought processes). Against this must be set, in some cases, the possible decreased accuracy of the habitual smoker when he has for some hours been deprived of his customary tobacco-combustion products, which might tend to prevent the appearance of the normal effects of smoking.

3. There is no indication that speed of complicated reactions is affected by smoking. Nor is there indication that thoroughly mechanized reactions requiring no fine motor adjustments, are affected. This would apply to the motor processes and thought processes of the man in an ordinary clerical or other subordinate business position, or those of a chauffeur. With regard to men engaged in intellectual work, and billiard players, the situation may be different.

4. If there is any effect of smoking on speed of reaction, and on efficiency in routine activity, it is clear that tests of the type used in this work; which are samples of the usual psychophysical tests, are not competent to show them. While further work with some of these tests is highly desirable, it is evident that for completion of an experimental program we must turn to the type of test devised by Professor Dunlap for use in

the Air Service, in measuring the effects of asphyxiation; since tests of this type will detect changes in mental capacity which entirely escape the older forms of test.

5. The examination of the immediate effects of tobacco smoking constitute but a small part of the necessary research program. Investigation of the remote effects; of the habituation to regular smoking; and of the immediate and remote effects of deprivation of tobacco must be made. Further, the effects on men must be compared with those on women. Finally, the effects on learning must be discriminated from the effects on habitual reaction.

6. In further research, the work must be very much more extensive in number and type of reactors, and more intensive in amount of measurement on the individual reactor, than has been in previous work. Further work such as that here reported would be a waste of time. Methods and technique must be much more refined than they have been in the past.

7. From casual measurements such as here described, we conclude that "physiological" changes (if any) due to tobacco smoking, should be investigated by modern methods, and these changes (if any) correlated with mental changes. Blood pressure changes, for example, should be carefully investigated by the simple but efficient method developed by the psychologists in the Air Medical Service, and the cause of blood pressure variations for long periods with and without smoking should be determined.

8. Finally, it is imperative that provision be made for keeping reactors under control, as regards smoking, diet, rest, mental and physical work, sex activity, etc., for long periods of time. This will be an expensive matter, but is ultimately unavoidable.

A bibliography on the effects of tobacco smoking will be presented in connection with a later investigation from this laboratory.

A STUDY OF THE SPONTANEOUS ACTIVITY OF THE GUINEA PIG[1]

EDITH E. NICHOLLS

Department of Physiology, School of Hygiene and Public Health, The Johns Hopkins University

INTRODUCTION

In the past decade various investigators have studied spontaneous activity in vertebrates in the hope of throwing some light on the fundamental problem of the relation between metabolism, activity, rest and fatigue in these animals. The following paper deals with a study of this problem in the case of the guinea pig.

It is generally believed among laboratory workers that guinea pigs are very quiet animals. They will sit quietly in a corner of the cage for many hours when anyone is near them. This inactivity is apparently due to an inhibition from fear. If guinea pigs are placed in a quiet enviroment under normal conditions of temperature, humidity, and illumination they are found to be almost continually active. This condition so far as is known is unique among mammals. In the following paper we describe how, by means of activity-recording cages, continuous records extending over several months have been obtained which show the activity of the guinea pig to be organized on an entirely different plan from that of other rodents such as rats and mice, and, indeed, of other mammals. Periodic alternations of complete rest and activity are conspicuously absent. Continuous and intermittent activity periods are present in the records but there are no indications of protracted intervals of sleep, which are familiar phenomena with rats, mice and other mammals. There is likewise an absence of both diurnal and nocturnal rhythm.

---

[1] This paper was presented as partial fulfillment of the requirements for the degree of Doctor of Science in Hygiene, School of Hygiene and Public Health, Johns Hopkins University. The work was carried out in Dr. W. H. Howell's laboratory in the Department of Physiology under the direction of Dr. Reynold A. Spaeth. I am indebted to Dr. Howell for numerous helpful suggestions and to Dr. Spaeth for constant supervision and criticism. In the observation experiment I was assisted by Dr. and Mrs. R. A. Spaeth and Miss Jean C. Snyder to whom I gladly acknowledge my indebtedness.

Studies have been made of the influence of changed environmental conditions and the relation of forced activity to food and rest.

The activity of the guinea pig and the rat has also been compared under identical conditions. In its activity the guinea pig is physiologically most nearly comparable to the vertebrate heart. By combining a high rate of metabolism with a scattered distribution of short rest periods, long rest periods and possibly sleep also, become superfluous. We are not prepared to say that the guinea pig never sleeps. Our records show however that if the guinea pig does sleep it is either (1) for very short periods or (2) combined with an activity that approaches somnambulism.

Previous experimental studies of mammalian activity

Studies of spontaneous activity and rest have hitherto been largely limited to the invertebrates or lower vertebrates. Surprisingly little work has been done upon mammals.

Slonaker (1907) studied the spontaneous activity of white rats in revolving cages and found that the amount of activity varied with age. He found that the age of greatest activity as represented by the number of revolutions of revolving cages ranges from 87 to 120 days. The rat spends much more time in rest than in activity and is more active at night.

The most entensive studies have been made by Szymanski (1920). He found the white, gray and dancing mouse spent about half their time in activity and half in quiet, the time of activity ranging from 10 to 14 hours. The dancing mouse showed one long activity period of 10 hours and seven very short periods alternating with periods of quiet. The white mouse had sixteen short periods of activity alternating with periods of quiet and the gray mouse twenty-three activity periods of even shorter duration during the twenty-four hours.

The white rat showed 10 hours of activity broken into ten short periods. The rabbit showed 12 hours of activity divided into twenty-one short periods and twelve of quiet similarly divided. The cat had only 4.5 hours of activity divided into seven different periods and the dog 6.75 hours divided into thirteen periods. The young infant showed 10 hours of activity and 14 hours of quiet. In all of these animals, with the exception of the dancing mouse, there is little difference in the amount of activity during the twelve hours of the day as compared with the twelve hours of the night.

Richter (1921) found that the white rat showed four to ten activity periods during the twenty-four hours and was most active during the night. He also found that the amount of activity decreased with age.

No studies have so far been made of the amount of activity and quiet of the guinea pig. Allen (1904) states that the guinea pig seems to be more active in the dark, than in the light, but she made no experimental study. The general impression among animal experimenters seems to be that in the laboratory, guinea pigs are unusually quiet animals. It is interesting to note, however, that guinea pigs apparently never assume a characteristic sleeping pose like that of a dog or rat or mouse, and that thus far we have failed to find anyone who recalls having seen a guinea pig sleeping.

APPARATUS

The apparatus used to determine the amount of activity of the guinea pig was similar to the one used by Richter (1921) in his work on the activity of the rat (fig. 1). It consisted of an equilateral triangular cage 25 inches on each side. The bottom was made of plaster board reinforced on each side with narrow strips of wood. The sides were made of 14 mesh mosquito netting, 8 inches high. Each cage weighed about 2 pounds. This cage rested upon the points of three large screws 1 inch in length. The screws had their heads soldered to small metal discs about an inch in diamter (fig. 1, *D*). These discs rested upon rubber membranes (*M*) which were stretched over the top of specially constructed brass cups (*C*). These cups were 1.25 inches deep and 2.12 inches in diameter and at the center of the bottom a metal nipple (*N*) 1.25 inches long was inserted. Holes were bored in the table on which the apparatus was assembled and the metal nipples projected through these holes. The cups then rested upon the table. The rubber tubing from the three metal cup nipples was brought together by means of a glass four-way connection. A long piece of tubing joined the four-way connection to a Harvard tambour writing-lever. Any movement of the cage was transmitted by air pressure through the cups to the tambour and then to the kymograph via the writing lever. The cages were made as light as possible so as to rest easily upon the rubber membranes and to increase their sensitivity. Respiratory movements were not recorded but all such muscular movements as quiet eating, scratching, etc. were recorded. The records were taken on a long-paper kymograph.

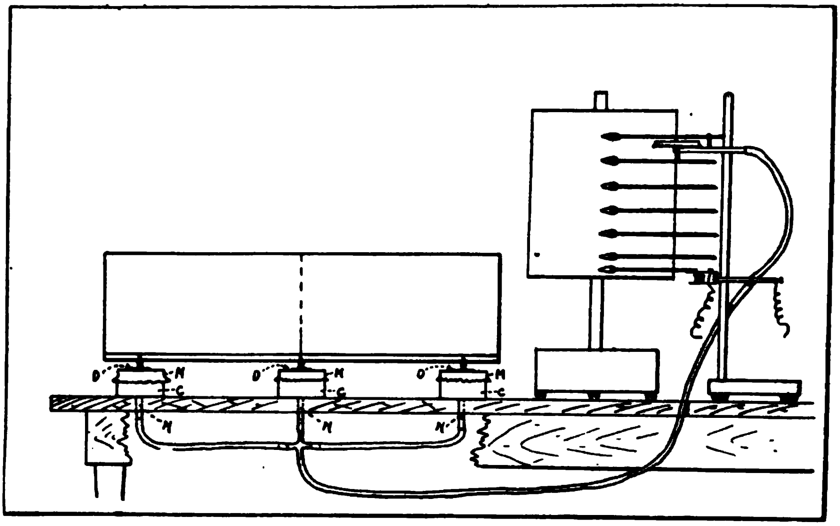


FIG. 1. DIAGRAM OF THE SCHEME OF THE APPARATUS USED IN THE ACTIVITY RECORDING EXPERIMENTS. SEE TEXT FOR DETAILS

All activity experiments were carried on in a brick vault 20.3 feet long and 7.51 feet wide which was 15 feet below the surface of the ground. This vault in the former Physics Laboratory of Johns Hopkins University was especially constructed by Dr. Rowland for his dividing engine. It was designed to maintain a constant temperature and humidity and to be free from all vibrations. All these variables had to be kept constant in the present experiments and thus the vault offered ideal conditions. A further advantage was the absence of noise. The temperature in the dark was 19.5°C. and never varied more than one degree in either direction. When the room was lighted by two 75 watt nitrogen daylight bulbs the temperature rose about two degrees and then remained constant. The relative humidity in the dark was 42 per cent and in the light 44 per cent as measured by the sling psychrometer. No one was allowed to enter the room except the experimenter, and then only long enough to feed the animals and change the paper on the kymograph.

MATERIAL

All the guinea pigs used in these experiments were of healthy stock and varied in size from 200 grams to 300 grams. They were all of the common short-haired variety. In all experiments when a group of animals was used, half were males and half were females. The guinea pigs were kept in the vault for at least a week before they were used in any experiment so as to become accustomed to the new environment. To guard against the possibility of stimulating activity by the slight movement of the recording-cage floor the pigs were kept during this preliminary stage in a special cage set on springs. The movements of this cage closely simulated those of the recording-cage. The food consisted of oats and water which the animals had in their cages all of the time and three times a week they were given cabbage and carrots. The bedding consisted of 1 or 2 inches of cut hay. The guinea pigs that were being used during an experiment were kept in the vault all of the time even when no record was being taken of their activity. The vault apparently offered a splendid environment for the growth and development of the guinea pig. The growth curve of the animals used followed closely the growth curve for guinea pigs as plotted by Minot (1891). It was found that if guinea pigs were taken upstairs into the animal room, after being in the vault for some time, they soon lost weight, became ill and frequently died.

The guinea pigs were handled constantly and became very tame. After a week or ten days they would not be frightened by the experimenter's entering the vault and instead of remaining quiet they would run about their cages squealing noisily. There were no deaths in the vault.

ACTIVITY OF THE GUINEA PIG

Activity in the dark

As it is generally believed that the guinea pig is most at home and most active in the dark, the first set of experiments, which endeavored to put the guinea pig in his most natural environment, was carried on in the dark.

Six healthy guinea pigs, three males and three females, whose weight ranged from 182 to 316 grams, were chosen for the experiment. They were taken into the vault and each was put into a separate recording-cage. They were given cut hay for bedding and oats and water. They were kept in their respective cages for three days before any records were taken of their activity so as to become accustomed to their new surroundings. The light was turned on for about fifteen minutes each morning during feed-time, but otherwise the room was in total darkness. There were no cracks where light could enter as the room opened by a tight fitting door into a larger room which was also dark. The doors both at the top and bottom of the steps which led into the vault were kept shut. There was therefore no possible way for any daylight to enter the rooms.

The experiment was started at nine o'clock in the morning and was continued for a week, every movement of the six guinea pigs being recorded throughout this period. A single kymograph sheet contained the activity of the six guinea pigs for twenty-four hours. The activity of each guinea pig was recorded, one directly under the other, with a time line at the bottom marking each hour. Thus in a week seven separate records were obtained, each showing the activity of six guinea pigs for a period of twenty-four hours. Three separate weeks' records in the dark were made in all. One was made in the spring, one the following fall, and one a few weeks later in the fall.

In all the records there was the same general picture. The guinea pigs showed almost continuous activity (fig. 2). The activity was divided into two phases; (1) periods of "continuous" activity in which there were no rest or quiet periods and (2) periods of "intermittent" activity in which there were a number of quiet periods varying in length from a fraction of a minute to ten minutes. There were no long rest periods whatsoever in any of the records. The periods of continuous activity varied in length from five minutes to several hours. These periods alternated with the periods of intermittent activity and were always considerably longer than the latter. There was a tendency for the six guinea pigs to be continuously active at the same time. This point will be discussed later in the paper. During continuous activity the movements were more violent than in the periods of intermittent activity.

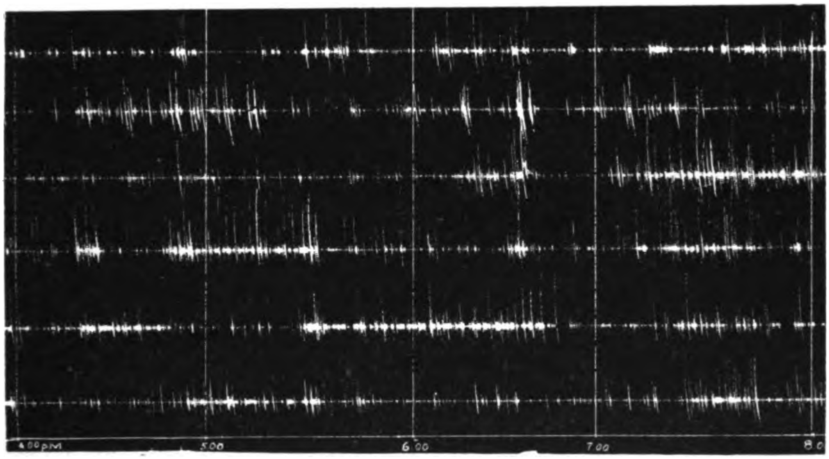


FIG. 2. THE ACTIVITY OF SIX GUINEA PIGS IN THE DARK

Besides a careful study of the records, it was thought advisable to devise a method by which to obtain a numerical criterion of the actual amount of activity shown by each guinea pig. In this way the amount of activity of the six guinea pigs could be compared with each other on the same and on different days. The activity of one guinea pig could also be compared on the seven different days. We hoped to obtain a numerical figure which represented the approximate amount of activity of a guinea pig in the dark for twenty-four hours.

The method finally decided upon was to measure all activity periods which contained no quiet periods of 2.5 minutes (⅛ inch) or more in length. This was done by means of a small map measurer. The instrument was set at zero, placed at the beginning of an activity period, and run along until it came to a quiet period an eighth of an inch or more in length. The instrument was then carefully lifted from the paper and put down again on the other side of this quiet period and run along until another quiet period ⅛ inch or more in length appeared in the record. The total amount of activity in feet and inches was then recorded. Only twenty-three hours were measured, the hour between nine and ten in the morning not being counted. During this hour each day the paper was changed on the kymograph and there was a loss of time varying from five minutes to half an hour. The guinea pigs were continuously active at this hour, partly because they were fed, but also because of the disturbances of the light and the presence of the experimenter. Conditions thus being not comparable with the other hours of the day, it was thought best to eliminate this hour.

The total length of paper which represented the twenty-three hours was measured from the time line, and the number of inches of paper which represented one hour was determined by dividing the total length by twenty-three. The total number of inches of activity was then divided by the length which represented one hour and the amount of activity in time was determined. The results were tabulated in chronological order and the averages obtained. By practice a fair amount of accuracy was obtained in measuring the amount of activity and the error did not vary more than plus or minus three per cent of the distance measured.

This method demonstrated the extreme activity of guinea pigs in the dark. Out of the 23 hours, the smallest amount of activity for any one animal was 17.5 hours and the largest amount 23 hours. The averages for individual records of the six guinea pigs for seven days varied from 19.69 hours to 21.73 hours out of the 23, and the average total activity for all six guinea pigs in the dark was 20.8 hours out of the 23, or at the rate of 21.6 hours out of the 24. The absolute activity for 24 hours was actually greater than the calculated 21.6 hours, since during the anticipatory excitement of feeding the animals were in continuous motion. The small amount of rest was broken up into numerous short periods averaging 3 to 4 minutes in length. The longest rest period on any record was 10 minutes.

The quiet periods of less than $\frac{1}{8}$ inch were measured with the total amount of activity for two reasons. First, in measuring the length of the activity periods it was impossible to leave out the quiet periods of less than one-eighth of an inch without introducing a considerable error. The measuring instrument had to be lifted from the paper a great many more times and this factor increased the possibility of error in the total length. Secondly, the quiet periods of less than $\frac{1}{8}$ inch are approximately $\frac{1}{32}$ to $\frac{1}{16}$ of an inch in length which represents but 0.6 to 1.2 minutes in time. It was found by observation that slight movements such as quietly chewing were not recorded by the levers and these might account for some of the periods. The guinea pig is also extremely sensitive to sounds even those caused by the gnawing or scratching of other guinea pigs. Whatever the cause of these momentary quiet periods they are more or less constant in all of the records and as all the records are measured in the same way they can be compared with each other without introducing an error.

Activity in the light

The next set of experiments was carried out under exactly the same conditions as those in the previous experiment with two exceptions. The room in this case was constantly lighted by two 75-watt nitrogen daylight bulbs which were suspended directly over the cages. These lights raised the temperature about 2°. This small increase in temperature probably failed to affect the activity records in any significant way (vide infra table 4 and fig. 6). The same set of guinea pigs was used as in the above experiment. They were left in their separate cages for three days, so as to become accustomed to the light before any records were taken.

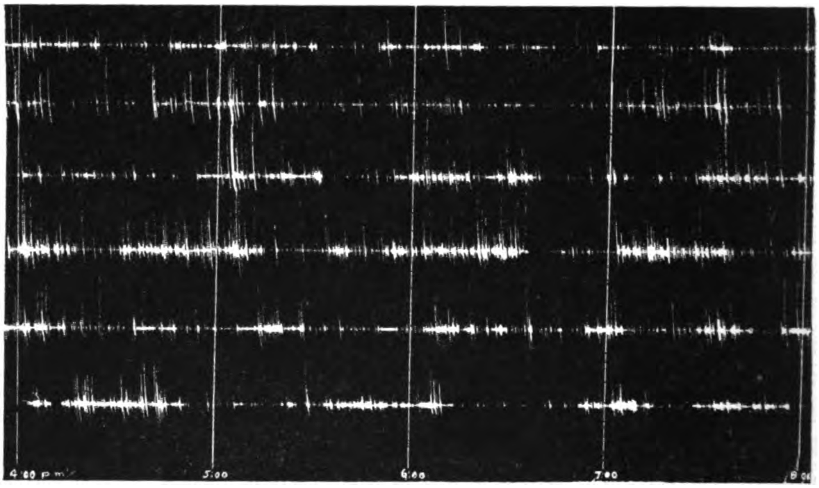


FIG. 3. THE ACTIVITY OF SIX GUINEA PIGS IN THE LIGHT

In this case the pigs are the same as those shown in figure 2

The experiment was started at nine o'clock in the morning and was continued for a week. Two sets of records in the light were taken about two months apart. In the first set, the paper was changed every twenty-four hours, and in the second the drum was run faster and the paper was changed every twelve hours. The records obtained were tacked on the wall beside the set taken in the dark and the two were compared. There was practically no difference in the two sets of records (fig. 3). There was the same general picture of extreme activity broken up into periods of "continuous" activity and periods of "intermittent" activity. These periods were essentially similar in both dark and light records and the rest periods were not typically longer or any more frequent in the light than in the dark.

By actually measuring the activity periods, as in the previous experiment, the following figures were obtained: Out of the 23 hours the smallest amount of activity for any one guinea pig was 15.6 hours and the greatest 22.6 hours. The individual averages for the six guinea pigs for 7 days varied from 19.4 hours to 21.53 hours and the average activity for all six guinea pigs for a week in the light was 19.83 hours out of 23 or at the rate of 20.64 hours out of the 24. Thus in comparing the total activity of the six guinea pigs in the dark with the total activity in the light, there was 1 hour less activity in the light per day, or a decrease of 4.6 per cent.

Distribution of activity

The guinea pig divides his time into periods of "continuous" activity and periods of "intermittent" activity. It is difficult to count the exact number of periods of each, since the periods frequently run into each other. Roughly, they vary from fourteen to twenty-three of each. The continuous activity periods vary in length from five minutes to three or four hours and their length does not correlate in any way with the following period of intermittent activity.

The absence of any correlation between activity and time of day was demonstrated by plotting the continuous activity periods of the same guinea pigs on three different days. Periods were chosen of over ten minutes in length which were broken by no quiet periods. No tendency was found for the guinea pig to be active at the same time each twenty-four hours. The activity furthermore is quite evenly distributed over the twenty-four hours and there is no nocturnal or diurnal rhythm. The periods of "continuous" activity are greater in length than the periods of "intermittent" activity.

Comparison of the activity of single animals and groups

The question arose as to the possibility of the six guinea pigs stimulating each other and thus increasing their normal amount of activity. In order to decide this question an experiment was carried out in which a guinea pig was placed alone in the vault and his activity recorded. This procedure was repeated using different guinea pigs and two days' records were taken of each animal. In two further experiments the activity of two guinea pigs and a group of six guinea pigs was studied. The same guinea pigs were used throughout the experiments. The work was carried out in the dark.

The records were measured and the average activity for the different groups was determined. The results were as follows:

	hours
Activity for one guinea pig alone	20.55
Activity for two guinea pigs, side by side but in separate cages	21.55
Activity for six guinea pigs in a group of separate cages	20.38

From these results there is apparently no significant difference in the amount of activity of the guinea pig whether alone or in groups.

Influence of age upon activity

Slonaker (1907) and Richter (1920) both found in the study of the white rat that the amount of activity decreases with age. A set of experiments was therefore carried out to see if this was true in the case of the guinea pig.

Records were taken in the dark of the activity of four young guinea pigs one month old. Records were also taken of four adult guinea pigs between eight and nine months old. We had at hand records of six guinea pigs three months old and of the same guinea pigs six weeks later. The results obtained by measuring the amount of activity are as follows:

	hours
Average activity of guinea pigs one month old	21.19
Average activity of guinea pigs three months old	21.6
Average activity of guinea pigs four and a half months old	20.38
Average activity of guinea pigs eight months old	21.18

There is thus apparently little difference in the amount of activity of guinea pigs ranging in age from one to nine months. The records of the older guinea pigs have the same general appearance as those of the younger. The amplitude of the movements is higher with the older guinea pigs because of the increase in weight.

Relative activity of males and females

In the experiments on the activity of guinea pigs in the dark and in the light in each case three male and three female guinea pigs were used. A study was made of the activity of each group to see if the amount of activity varied with the sex. Richter (1921) found in the case of the white rat that in the revolving drum the females were more active than the males.

TABLE 1

The amount of activity of three male and three female guinea pigs in the dark for seven days

	MALE			FEMALE		
	Guinea pig A	Guinea pig D	Guinea pig F	Guinea pig B	Guinea pig C	Guinea pig E
Weights, grams	222	261	316	236	182	255
Date	Activity			Activity		
October 18	20.5	22.8	22.3	19.6	20.8	23.0
October 19	22.5	20.8	17.5	19.2	18.8	18.2
October 20	21.8	23.0	20.0	20.9	21.5	22.5
October 21	20.6	21.4	18.3	20.2	22.1	20.9
October 22	20.3	19.7	20.8	18.5	—	19.2
October 23	22.4	22.9	21.8	20.6	22.0	20.7
October 24	20.6	21.2	21.7	19.8	—	21.9
Averages	21.24	21.73	20.34	19.69	21.04	20.81
Average 23 hours	21.10			20.51		
Average 24 hours	22.01			21.40		

Table 1 shows that in the dark the average amount of activity during 24 hours for three female guinea pigs was 21.40 hours and of three male guinea pigs 22.01 hours. The male guinea pigs show in this case an increase of activity over the females of 0.61 hours. In the light (table 2) the females showed 20.44 hours of activity and the males 21.18 hours, with an increase in the case of the males of 0.74 hours. Thus both in the light and in the dark male guinea pigs show a slightly greater activity than the female guinea pigs, under the conditions of our experiments.

The influence of food upon activity

The guinea pig is an herbivorous animal and spends most of his time eating. An attempt was made in this set of experiments to determine the part that food plays in the activity of the guinea pig. If food is partially or completely removed will the guinea pig still continue to be as active as normally?

TABLE 2

The amount of activity of three male and three female guinea pigs in the light for seven days

	MALE			FEMALE		
	Guinea pig A	Guinea pig D	Guinea pig F	Guinea pig B	Guinea pig C	Guinea pig E
Weights, grams	251	299	330.5	271	207	286
Date	Activity			Activity		
October 26	21.9	20.0	18.9	18.9	19.2	16.9
October 27	20.3	22.6	20.9	19.9	19.0	22.0
October 28	20.7	19.9	21.6	19.9	19.1	20.0
October 29	21.9	21.9	21.2	22.2	21.2	21.7
October 30*	10.7	10.8	11.4	10.1	10.6	11.1
October 31	22.6	18.9	18.6	19.8	20.6	19.9
November 1	21.8	18.0	15.6	19.0	17.3	16.1
Averages	21.53	20.21	19.46	19.95	19.40	19.43
Average 23 hours	20.40			19.59		
Average 24 hours	21.18			20.44		

* On a run of 12 hours.

Food one hour a day. The same six guinea pigs were used as in the previous experiment and the work was carried out in the dark. All food and bedding was removed from three of the recording-cages and paper bedding was substituted for the hay. At nine o'clock in the morning the six guinea pigs were weighed and the experiment was started, three guinea pigs being without food and three controls with food. The next morning at nine o'clock the six animals were again weighed and the three guinea pigs without food were given food for one hour. Water was left in the cages all of the time. At the end of the hour all the food was again removed from the same three cages. This was continued for seven days and records were taken of the amount of activity and rest. The guinea pigs were always weighed at nine o'clock in the morning just before they were fed. The three control animals were also weighed at this time.

As in the previous experiments, the activity for twenty-three hours only was measured. The time between 9 a.m. and 10 a.m., when the guinea pigs were fed and the recording paper was changed, was not counted. From the data obtained the average individual activity for the three guinea pigs fed for 1 hour a day for 7 days was 21.33 hours, 22.0 hours and 20.93 hours, making a total average of 21.42 hours of activity in the 23 hours for all three guinea pigs, or at the rate of 22.2 hours in the 24. The three control guinea pigs showed individual averages of 21.95 hours, 21.05 hours and 21.5 hours for 7 days, a total average of 21.5 hours of activity in 23 hours, or at the rate of 22.3 hours out of 24 hours. Thus the three guinea pigs without food showed no significant decrease in activity although the amount of food eaten each day was considerably less than that of the three control guinea pigs.

Since there was no decrease in activity, we expected to find a loss in weight each day and this was actually the case. One guinea pig showed a loss in weight of 41 grams the first day and only had 13 hours of activity. The cause of this great loss both in weight and activity was quite obscure. Guinea pig F did not show any loss in weight the first day and guinea pig D showed a loss of 10.5 grams. The controls showed gains of 6.5 grams, 5 grams and 5 grams the first day. The average loss in weight for the week for the three guinea pigs without food was 29.8 grams while the average gain for the control animals was 11 grams. It is fair to assume that if the three guinea pigs without food had been given their normal rations for the week they would not only have maintained their original weight but would probably have shown a proportional increase of weight of approximately 11.0 grams like the controls. Therefore the total average loss in weight for the three fasting guinea pigs may be considered as 40.8 grams or 13.6 grams per guinea pig. Thus the fasting guinea pigs maintained their normal activity, but at the expense of their body weight.

No food. As a check on the above experiment another one was carried out in which three guinea pigs were not given any food at all for three days. This time the food and cut hay bedding were removed from three of the cages and no paper bedding was substituted. Wire mosquito netting was put over the bottom of the cages so as to prevent the guinea pigs from nibbling the plaster board. Three healthy guinea pigs were chosen all weighing over 300 grams. Three similar pigs were chosen for controls.

The guinea pigs that were to be starved were weighed and the experiment was started. The following day at the same hour the three guinea pigs were again weighed and again on the second and third day. At the end of the first day the three guinea pigs without food seemed very restless and ran about their cages squealing. On the second day one seemed sick while the other two were quite lively. On the third day all three sat humped up with their eyes partly closed and semed to move with difficulty. They were given food gradually and within a week they were weighed again and all but one had regained his original weight.

The records obtained were measured in the usual way. The first day the starved guinea pigs showed an average amount of activity of 15.6 hours while the controls had an average of 18.4 hours. On the second day, the starved guinea pigs showed an average activity of 18.7 hours as compared with 18.5 hours shown by the controls. On the third day, the three starved pigs showed 7.1 hours, 7.1 hours and 7.6 hours of activity respectively, making an average of 7.3 hours. The controls had 17.3 hours. Thus on the first and second day there was little falling off of activity as compared with the controls but on the third day the amount of activity decreased over 50 per cent.

In comparing the activity with the loss in weight, we find the loss the first day was the least, i.e., 6.0 grams, 6.5 grams, and 7.0 grams. The loss on the second day was much greater—24.0 grams, 33.5 grams, and 31.5 grams. This was also the day on which the average amount of activity was the greatest. On the third day the loss of weight was 21.5 grams, 19 grams, and 21.0 grams. As in the previous experiment the three guinea pigs continued their activity at the expense of their body weight up to a certain point.

It is interesting to note in this experiment that the control guinea pigs did not show as much activity as was found in previous experiments. As these guinea pigs were the same as were used in many of the other experiments this absence of activity may have been due to the influence of the starved guinea pigs. The control guinea pigs showed their smallest amount of activity on the third day when the activity of the starved animals had fallen off over 50 per cent. The reduced activity of the fasting guinea pigs may therefore have had an inhibiting effect upon the controls.

The influence of physical exhaustion upon activity

In this set of experiments we studied the relation between physical exhaustion produced by forced running in a motor-driven drum and subsequent activity. In some of the experiments a separate food cage was connected to the main cage by a small opening. The food cage was set upon separate tambours and all movements were recorded independently on the drum. The purpose of this set-up was to determine the amount of time the guinea pig spent in the food cage.

Six guinea pigs were used varying in weight from 245 to 314 grams. Similar guinea pigs were used as controls. A guinea pig was weighed and placed in the motor-driven drum and made to run until he was exhausted. An animal was considered exhausted when he lay on his back or side and let the cage slide under him and when he remained in the same position for some minutes after the drum was stopped. He was again weighed and immediately taken down into the vault and put into the recording-cage for two hours. The records were spread out more than in the earlier experiments in order to emphasize individual movements. The six guinea pigs were exhausted in the same manner and records were taken of their behavior afterwards.

In all of the records the guinea pigs remained quiet for ten or fifteen minutes and then began eating. They ate continuously while they were in the cage. The records show a continuous line of small movements such as are registered by eating and there are few vigorous movements. Where the food cage is attached the records show that within a few minutes the guinea pig entered the food cage and remained there for what remained of the two hours, eating all of the time. The records of the control guinea pigs showed more vigorous movements and considerably less eating movements.

TABLE 3

Data concerning six guinea pigs fatigued to the point of extreme exhaustion

GUINEA PIG	WEIGHT	NUMBER OF REVOLUTIONS	DISTANCE	TIME	LOSS IN WEIGHT
	grams		*miles*	*hours*	
E	245	789	0.81	3	3
A	249	793	0.82	2.25	6
D	254	757	0.77	3.41	5
C	264	709	0.73	3.16	6
B	309	1636	1.67	4.75	6
F	314	1951	1.99	5.83	5

Upon observation the three guinea pigs sat humped up beside the dish of food, with their eyes partly closed but chewing vigorously. They did not move their position when the experimenter entered the vault or show any fear when touched. They did not respond to any stimulus except the one aroused by the desire for their food.

It seems therefore from these results that eating is more essential than sleeping in the recovery of guinea pigs from fatigue.

It is interesting to note that the heavier (older) the guinea pig the longer it took for him to become exhausted. Data concerning the weights of the pigs and the times and distances run are given in table 3.

The influence of temperature upon activity

During the first part of the experimental work we observed a constant tendency in our guinea pigs to stretch out on the bottom of the cage and remain inactive for long periods when the temperature was between 75° to 80°F. This was not an inhibition because of fear as the guinea pigs were all very tame. These long periods of inactivity were believed to be caused by the high temperature and the matter was further investigated by the following experiment.

Three young guinea pigs were put into separate recording-cages in a small room in the vault. The rubber tubing from the cages was passed through small holes in the door frame and connected with the recording device outside the door. The door was kept shut and was opened only a few minutes each day to give the guinea pigs fresh water and food. The room was heated by a Majestic electric heater. A Friez thermograph recorded the temperature.

TABLE 4

The influence of temperature upon the activity of the guinea pig

DATE	TEMPERATURE 12 NOON	GUINEA PIG A	GUINEA PIG B	GUINEA PIG C	AVERAGE ACTIVITY
April 4......	65°	17.3	20.6	19.1	19.0
April 5......	65°	21.7	20.4	21.8	21.3
April 6......	65°	21.2	23.4	21.0	21.8
April 7......	65°	21.2	22.8	20.0	21.3
April 8......	79°	17.0	20.0	20.3	19.1
April 9......	83°	15.8	17.3	16.3	16.4
April 10.....	85°	10.0	13.0	13.4	12.1
April 11.....	85°	12.7	13.3	11.6	12.5
April 12.....	79°	15.1	15.3	14.9	15.1
April 13.....	84°	12.0	11.3	7.7	10.3
April 14.....	86°	10.8	9.0	7.7	9.1
April 15.....	87°	10.4	12.1	10.7	11.1
April 16.....	87°	8.3	7.5	8.1	7.9

Records were taken of the amount of activity of the guinea pigs at the normal dark temperature of the vault, 65°F., for four days. The electric heater was then turned on for four days and records were taken of the activity of the guinea pigs. The heater was turned off for twenty-four hours and then put on again for four days, and activity records were taken.

The records were measured in the usual way and the amount of activity for each day is recorded in table 3. The average amount of activity for the three guinea pigs at the normal temperature of the vault, 65°F., was 20.8 hours. As the temperature increased the amount of activity decreased (see fig. 4). At 79° there were 19.1 hours of activity and at 85° there were 12.1 and 12.5 hours of activity. When the electric heater was turned off for 24 hours the temperature fell to 79° and the amount of activity rose to 15.1 hours. The room was again heated and the temperature rose to 87° and the amount of activity decreased to 7.9 hours on the last day.

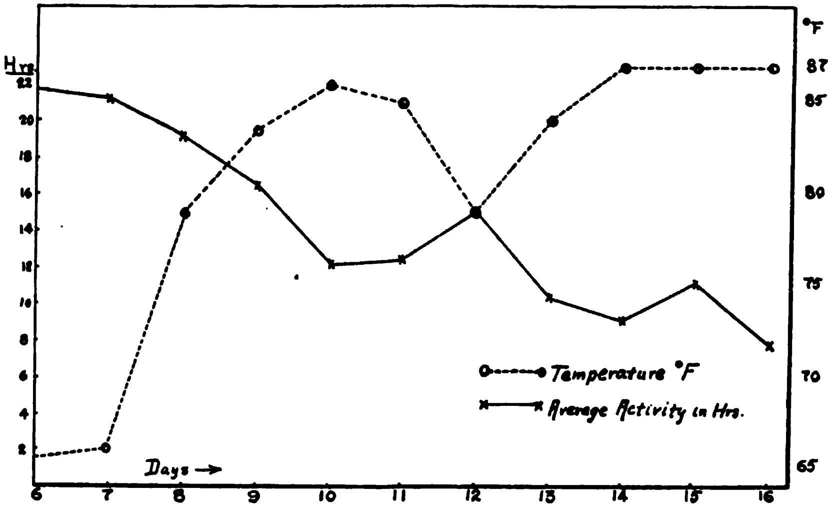


FIG. 4. THE RELATION BETWEEN ACTIVITY AND TEMPERATURE

The activity curve is an average activity of three pigs for twenty-four hours. The temperatures were read from the thermograph tracing at 4:00 p.m. on each day of the experiment. See table 4 and text for details.

The general appearance of the records is quite different for the days when the temperature was high as compared with the normal activity records. The "continuous" activity periods are very short and are broken by short quiet periods. The amplitude of the movements is considerably reduced. There are long periods of absolute quiet which are never found in a normal activity record. We find from this experiment that there is a decided decrease in the activity of the guinea pig with an increase in temperature. The experiment therefore corroborates our casual observations of the reduced activity of guinea pigs at elevated laboratory temperatures.

The nature of the activity and rest of the guinea pig

From the records obtained of the activity of the guinea pig, it was found the activity was divided up into periods of continuous activity and intermittent activity. The latter contained numerous short quiet periods. The question therefore arose: Is the guinea pig practically continuously active with just snatches of rest or does he actually go to sleep and move in his sleep? The only way to settle the question was to watch the guinea pigs and find out by observation.

For this experiment a hole 5 inches long and 2.5 inches wide was cut in the door which led into the room where the experiments were in progress. The guinea pigs were placed as near the door as possible and a foot from the floor. It was found that only four cages could be conveniently observed at the same time. Long narrow mirrors were placed beyond the two farthest cages to aid in seeing the faces of the guinea pigs when their backs were turned toward the observer. The room was lighted by two 75 watt, nitrogen, daylight bulbs hung low over the cages. The observer sat on a stool on the other side of the door with his eyes about 6 inches from the hole.

The experiment was started at 11:30 in the morning and continued until 11:30 the next morning. During the day the observer watched for periods of two to four hours but from nine o'clock in the evening until seven the next morning the shifts were never over two hours. This was to prevent loss of interest from fatigue on the part of the observer. The four guinea pigs were watched constantly and every movement and any signs of rest were carefully noted. Observations concerning the condition of each of the guinea pigs were written down every five minutes and in many cases more often.

The following facts seem worth recording. The guinea pigs divided their time into constant activity and intermittent activity. During the former they ran about their cages, with occasional leaps and jumps, called out to each other, tried to climb up the sides of their cages and gnawed at the wire netting or drinking cups. They would play with their food, dig in the food dish and scratch for choice bits in their bedding. They were wide awake and free from any fear. During these periods all the guinea pigs were more or less simultaneously active. Their activity would increase to a certain pitch and gradually they would quiet down again. These periods were longer than the less active periods and more frequent. They would vary greatly in the pitch to which the activity rose.

The intermittent periods were slightly different. They might be divided into fear, quiet eating, and actual rest. The guinea pigs in this experiment seemed to be conscious most of the time of the presence of the observer, but this factor did not disturb them to a great extent as they were all very tame. However, moving the stool or dropping a book would startle them and thereafter they would sit quietly watching the hole in the door as long as fifteen minutes at a time. These periods of fear were rather frequent due to the short shifts.

The guinea pig would often sit beside the food dish eating quietly and it was noticed that very slight movements such as chewing slowly did not record on the drum. The guinea pigs spent most of their time eating. The actual rest periods were few and of short duration. A guinea pig would relax and settle into a little heap in a corner of the cage and even put his head down but he would never stay quiet for more than a minute or two at a time. He would constantly move, yawn, stretch himself, and make movements with his jaws. He would remain in this quiet state for some time but he would continually be interrupted by something and then settle down again. In these rest periods, the guinea pig would frequently partly close his eyes but in only one instance did an observer state a guinea pig had his eyes completely closed.

The actual amount of activity was measured on the record and also for the three succeeding days. It was found that during the twenty-four hours of observation, there was a considerable falling off from the normal amount of activity as previously determined. As stated above the guinea pigs seemed conscious of the observer and there was probably an inhibition from fear. This inhibition persisted to a less extent the next day and disappeared the second day. The exact data are shown in table 5.

TABLE 5

The amount of activity in hours of the four guinea pigs in the observation experiment and the three succeeding days

DATE	GUINEA PIG 1	GUINEA PIG 2	GUINEA PIG 3	GUINEA PIG 4
November 19 observation experiment	14.5	15.4	13.8	15.9
November 20	15.6	16.8	16.0	18.1
November 21	19.8	22.7	18.9	19.2
November 22	17.0	20.7	18.0	19.8

Comparative activity of the guinea pig and the rat

Before completing the experiments on the normal behavior of the guinea pig it was thought advisable to make some comparative studies with another animal. The white rat was chosen for this purpose for two reasons. It belongs to the same order as the guinea pig and its size is convenient. A male white rat is not much smaller than a young guinea pig. Furthermore, Richter (loc. cit.) has made an extensive study of the behavior of the rat.

In these experiments a study was made of the activity of the guinea pig and rat when together in the vault and also when alone. The animals were all males and were about two and a half months old. Four animals were put into separate recording-cages in the vault with a rat alternating with a guinea pig. As the cages were arranged in the form of a square a rat had a guinea pig pig on each side of him and a rat opposite him. All four cages were covered with mosquito netting. The wire netting was necessary to prevent the rats' escaping from their cages. It was put over the cages of the güinea pigs so as to make the conditions the same. The animals were given their customary diet. The guinea pigs had cut hay for bedding and oats and water. The rats were given paper bedding and oatmeal and milk. The experiments were carried on in the dark.

In the first experiment the four animals were taken into the vault and records were taken of their activity for periods of 24 hours. The records were then measured as in the previous experiments. This time the amount of rest was determined as well as the amount of activity. The two guinea pigs in 4 days showed an average activity of 22.28 hours while the rats showed 11.5 hours. Thus the guinea pig was almost twice as active as the rat. The guinea pig showed an average of 1.75 hours of rest and the rat an average of 12.5 hours. The guinea pig spent 93 per cent of the 24 hours in activity and 7 per cent in rest, while the rat spent 48 per cent of the time in activity and 52 per cent in rest.

There is a possibility in the above experiment that the rats and guinea pigs might have influenced each other to greater or less activity than normal. Therefore another experiment was carried out, in which the rats and guinea pigs were put in the vault alone and their activity recorded. The two guinea pigs were taken into the vault and their activity was recorded to 2 days, then they were removed and the two rats were taken down and their activity was recorded for 2 days. The guinea pigs showed an average activity of 21.25 hours and the rats an average activity of 9.87 hours. In the same period the guinea pigs showed 2.77 hours of rest the rats 14.1 hours. Thus the guinea pigs when alone spent 89 per cent of their total time in activity and 11 per cent in rest. The rats spent 41 per cent of their total time in activity and 59 per cent in rest. If we consider 9.87 hours, the amount of activity when the rat was alone as his normal activity, the relative increase in activity when the rat was with the guinea pig is 16.5 per cent while the guinea pig showed an increase of only 4.8 per cent. The extreme activity of the guinea pig may have disturbed the rat and prevented him from taking as much rest as would normally be the case.

In comparing the amount of activity during the day with the amount of activity during the night, the guinea pig and the rat are quite different. The day is taken from six in the morning to six at night and the night from six in the evening to six the next morning. The guinea pig shows 10.4 hours of activity at night and 10.8 hours during the day. The rat shows 6.27 hours

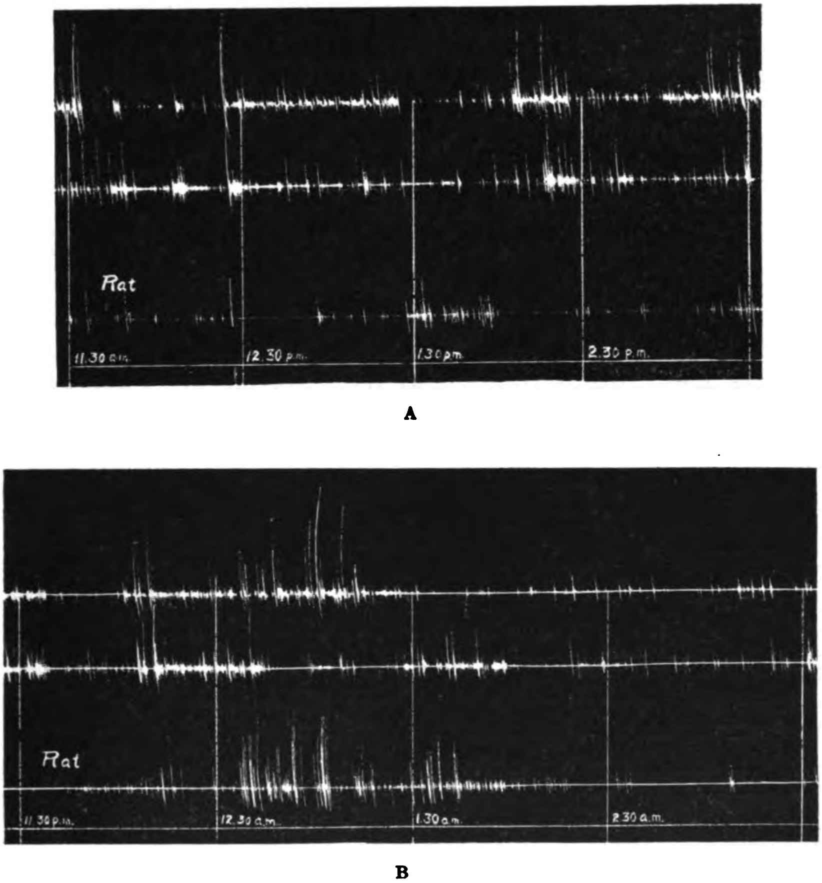


FIG. 5. THE RELATIVE DIURNAL (A) AND NOCTURNAL (B) ACTIVITY OF ONE RAT AND TWO GUINEA PIGS TAKEN ON THE SAME RECORD OF TWENTY-FOUR HOURS IN THE DARK

Note the reduced general activity of the rat during the day of activity at night and 3.6 hours during the day. There is, therefore, an increase of activity at night of about 80 per cent which agrees with the well known nocturnal habits of the wild rat. The absence of a distinctly nocturnal habit in the guinea pig is strikingly demonstrated by the above figures. The relative activity of two guinea pigs and one rat from noon till 2:00 p.m., and from midnight till 2:00 a.m. are shown in figure 5.

CONCLUSIONS

1. When guinea pigs are placed in an environment free from abnormal and disturbing stimuli and under constant conditions of temperature (65° plus or minus 1°F.) and humidity (42 per cent relative) they are found to be extraordinarily active. There are no alternations of protracted complete rest periods and activity. The time is divided into periods of "continuous" activity and "intermittent" activity. During the former they are continuously active and in the latter the periods are broken by small rest periods averaging three to four minutes in length. There is no nocturnal or diurnal rhythm. In the dark, at a temperature of 65°F., they show an average activity of 21.6 hours out of 24.

2. With constant illumination and a temperature of 67°F. guinea pigs show an average activity of 20.64 hours out of the 24. The temperature rise of 2°F. is too small to account for the reduced activity. There is thus approximately 5 per cent less activity *in the light* than in the dark.

3. In comparing the activity of single animals and groups, it was found that the presence of other normal guinea pigs does not significantly affect the activity of a single pig.

4. There is apparently little difference in the amount of activity of guinea pigs ranging in age from one to nine months. The young guinea pigs showed an average activity of 21.19 hours, the three month old animals 21.6 hours, and the nine month old guinea pigs 21.18 hours.

5. In comparing the activity of the sexes, the male guinea pigs showed a slightly greater average activity than the females.

In the dark the difference is plus 2.8 per cent and in the light plus 3.4 per cent.

6. Guinea pigs fed for an hour a day showed a slightly higher average activity than when they had food in the cage all of the time. In the course of a week, however, they showed an average loss in weight per pig of 13.6 grams.

7. When three guinea pigs were given no food for three days, there was a falling off of activity from 15.6 hours to 7.3 hours. There was also a rapid decrease in weight.

8. When guinea pigs were fatigued to the point of extreme exhaustion in a revolving cage, upon being put back into their recording-cages, they immediately started to eat and continued to eat for at least two hours. It seems from these results that eating is more essential than sleeping in the recovery of the guinea pig from fatigue.

9. The amount of distribution of the activity of the guinea pig is influenced by the external temperature. At high temperatures (80–85°F.) the normal activity of the guinea pigs drops off over 50 per cent. At a high temperature they show short activity periods and long periods of quiet.

10. By observation it was found that during "intermittent" activity guinea pigs would settle into a relaxed condition but would never remain quiet for more than two or three minutes at a time. In these short rest periods the guinea pig would partly close his eyes and sometimes rest his head on the hay bedding. The guinea pig spends most of his time eating.

11. In comparing the guinea pig with the white rat, the guinea pig was found to spend 89 per cent of the twenty-four hours in activity and 11 per cent in rest. The rat was found to spend 41 per cent in activity and 59 per cent in rest. The activity of the guinea pig was evenly divided between the day and night. Our rats, however, were found to be 80 per cent more active at night than in the day.

12. It is certain that sleep does not play a rôle in the normal life of the guinea pig comparable to the sleeping of rats, mice and other mammals. We are not prepared to say that the guinea pig never sleeps, but, in an extensive inquiry among laboratory

workers, we have thus far failed to find anyone who recalls having seen a guinea pig sleeping.

REFERENCES

ALLEN, JESSIE 1904 The associative processes of the guinea pig. Jour. of Compar. Neurol. & Psychol., xiv, 293–359.

MINOT, C. 1891 Senescence and rejuvenation. First paper: On the weight of guinea pigs. Jour. of Physiol., xii, 97.

RICHTER, CURT P. 1921 The behavior of the rat. Dissertation. Johns Hopkins University, June, 1921.

SLONAKER, J. R. 1907 The normal activity of the white rat at different ages. Jour. of Compar. Neurol. & Psychol., xvii, 342–359.

SZYMANSKI, J. S. 1920 Aktivität und Ruhe bei Tieren und Menschen. Zeitschrift fur allgemeine. Physiologie, xviii, 106–161.

VOLUME II OCTOBER, 1922 NUMBER 5

THE JOURNAL OF COMPARATIVE PSYCHOLOGY

Continuing Psychobiology and the
Journal of Animal Behavior

EDITED BY
KNIGHT DUNLAP
Johns Hopkins University
AND
ROBERT M. YERKES
National Research Council

IN ASSOCIATION WITH

MADISON BENTLEY
University of Illinois

HARVEY CARR
University of Chicago

WALTER B. CANNON
Harvard University

RAYMOND DODGE
Wesleyan University

SHEPHERD I. FRANZ
Government Hospital for the Insane

GILBERT V. HAMILTON
Santa Barbara Clinic,
Santa Barbara, California

SAMUEL J. HOLMES
University of California

WALTER S. HUNTER
University of Kansas

HERBERT S. JENNINGS
Johns Hopkins University

GEORGE H. PARKER
Harvard University

EDWARD L. THORNDIKE
Columbia University

MARGARET F. WASHBURN
Vassar College

JOHN B. WATSON
New York City

WILLIAM M. WHEELER
Harvard University

PUBLISHED BI-MONTHLY BY
WILLIAMS & WILKINS COMPANY
BALTIMORE, U. S. A.

Entered as second-class matter April 4, 1921, at the post office at Baltimore, Maryland, under the act of March 3, 1879

Price per volume, net postpaid
$5.00, United States, Mexico, Cuba
$5.25, Canada
$5.50, other countries

Made in United States of America

We Announce for Early Publication

Two Important Volumes

Volume I

EUGENICS, GENETICS AND THE FAMILY

Volume II

EUGENICS IN RACE AND STATE

FOR

The Second International Congress of Eugenics

Committee on Publication

Charles B. Davenport, Chairman
Henry Fairfield Osborn, Ex Officio
Clark Wissler
H. H. Laughlin, Secretary

The Congress brought together in New York in September, 1921, four hundred of the leading students of heredity, of statistics, of anthropology, and of eugenics from the United States, England, France, the Scandanavian countries, Italy, Czecho-Slovakia, and South American countries.

One of the world's great paleontologists, geologists and biologists spoke to the Congress: "I doubt if there has ever been a moment in the world's history when an international conference on race character and betterment has been more important." The presence of so many leaders resulted in the presentation of THE MOST IMPORTANT PAPERS ON EUGENICS AND HEREDITY THAT HAVE YET APPEARED.

These papers will be published in two volumes, splendidly illustrated. No less that fifty illustrations of Exhibits, about twenty-five to each volume, will appear. The genetic and anthropological papers naturally fall into one group—*Eugenics, Genetics and the Family.* The papers on genealogy and applied genetics will appear under the title—*Eugenics in Race and State.* Those desiring a broad foundation for eugenics will want both volumes. Those desiring merely a special group of papers can obtain such papers in a single volume.

The volumes will be printed in such a way as to reflect credit upon the Congress and the science with which it deals. Printed on a fifty per cent rag paper, light natural color, bound in blue linen weave book cloth and stamped in gold. The illustrations will be printed on a special coated paper that matches in *color* the text paper. Size: 6 x 9 inches. About 400 to 450 pages to each volume. Over fifty papers to each volume.

If you are interested in Wells' "The Outline of History," Van Loon's "The Story of Mankind," or Osborn's "Men of the Old Stone Age," then you will read with a great deal of pleasure *EUGENICS, GENETICS AND THE FAMILY* and *EUGENICS IN RACE AND STATE.* NO WORK OF SUCH INTEREST AND THOROUGHNESS HAS APPEARED FOR MANY YEARS. The volumes ARE REPRESENTATIVE OF THE MOST MODERN KNOWLEDGE of the principal American, British, French and Scandinavian biologists and sociologists, and will be in wide demand.

Pre-Publication Prices, net, postpaid
for United States

Both Volumes	**Pre-Publication**	**$9.00**
	After Publication	**11.00**
Single Volume	**Pre-Publication**	**5.00**
	After Publication	**6.00**

For Canada, add 50 cents a volume. For other countries, add $1.00 a volume.

May be ordered from your own bookseller or order direct from the publisher.

Williams & Wilkins Company
Mount Royal and Guilford Avenues
Baltimore, Maryland

Gentlemen:

Enter my order for the volume(s) checked below:

Check Volume You Wish
☐ Volume I—Eugenics, Genetics and the Family
☐ Volume II—Eugenics in Race and State

Both Volumes...... { Pre-Publication $9.00 / After Publication 11.00 } Single Volume....... { Pre-Publication $5.00 / After Publication 6.00 }

When you make the shipment, mail me a statement, at price above noted, which I will pay. (Terms 30 days.)

Signed ....

Address ....

ATTENTION, DISTRACTION AND FATIGUE

F. C. DOCKERAY

Ohio Wesleyan University

INTRODUCTION

The experiments to be reported were designed to study certain factors involved in the capacity for mental work, or activity, under various conditions of distraction and mental and physical fatigue. In 1915 we published the result of experiments involving partial fatigue of isolated groups of muscles as well as of larger groups, or what might be called general fatigue.[1] The results on the whole were rather ambiguous, particularly with the addition and multiplication tests, though the sounder test there described seemed to offer more promising possibilities. It was assumed that the chief advantage of this test rested in the fact that speed of performance was controlled and the subject was required to discriminate the sounds at the given rate, thus allowing a single variable in his performance. The principal advantage of this was the added incentive. When speed and accuracy both depended upon the subject, there was a tendency to default in one or the other.

Further experiments with the sounder test were planned along two lines; first, the effects of continuous distraction for a period of fifteen or twenty minutes were to be investigated by Miss Emily Berger,[2] a graduate student at the University of

---

[1] The effects of physical fatigue on mental efficiency, Kansas University Science Bulletin, 1915, ix, 197–243.

[2] Miss Berger very faithfully performed her part of the task in the years 1915–17. The war then interrupted the work and nothing further was attempted until the spring of 1920. Then her sudden illness and death left the work still unfinished. The data, more or less disorganized by these conditions, was turned over to me and I have pieced them together as best I could. A great deal of the information for the interpretation of the results is missing, through no neglect of Miss Berger.—F. C. D.

Kansas, and second, the investigation of the effects of physical and mental activity under more controlled conditions than favored the earlier investigations were to be undertaken by the author. Miss Berger's experiments and a few preliminary experiments in mental fatigue are reported here, not so much because of their intrinsic interest as because they point out some of the errors affecting this type of investigation and also indicate the line of development of the test to be described in the second part of this report.

APPARATUS AND METHOD

The procedure was practically the same in these experiments as in the earlier tests. Four sounders, tuned to slightly different pitch and intensity, were sounded in irregular order, one every second. A fifth sounder, the intensity of which could be varied, sounded with each of the other four in order that the difficulty of discrimination could be more successfully regulated An important change in the method was the introduction of an apparatus for operating the sounders automatically.[3]

This automatic contact apparatus was designed somewhat on the order of a player piano except that instead of air currents through the holes in the paper electric contacts were made. Adding machine paper 4½ inches wide was used in which to punch the pattern, as it was the most conveniently obtained. Four rows of holes 2 mm. x 8 mm. were cut transversely along one side of the paper with a specially constructed punch. The rows were 2 mm. apart in the longitudinal direction of the paper while the holes occurred every centimeter, but seldom two holes in succession in the same row. The pattern so constructed was made as irregular as possible and as the paper was 180 feet long there was little possibility that a subject would memorize it. The signal indicating the sounder to which the subject should react was produced by cutting five holes in one row half as far apart as the regular interval followed by one regularly spaced in another row and a return to one regularly spaced in the same row with the signals. Thus, the five in one row serve as the signal, but the subject is given the added cue that he knows that the second one following the signal will be the same as the signal.

---

[3] Financial aid in the construction of this apparatus and for hiring subjects for the experiments was furnished by the Research Committee of the Graduate College of the University of Kansas. The first apparatus was constructed with this aid. Our transfer to Ohio Wesleyan University prevented the further use of the fund for the employment of subjects.

As the pattern of holes occupied only about one-third of the paper, the remaining two-thirds could be used for a permanent record of the subjects reactions. For this purpose an electric marker provided with an indellible pencil was employed. To make the record more distinct without the pencil resting too heavily upon the paper to ensure easy movement of the pencil a small sponge inserted in the end of a glass tube was so adjusted that it rested lightly upon the paper just ahead of the pencil and would dampen the paper slightly just before the paper passed under the pencil. The sponge was kept wet by keeping the glass tube filled with water. Later the method was somewhat improved by substituting a no. 2 fountain pen with the barrel removed. By keeping this clean it proved to be more reliable and more easily adjusted than the pencil. Though the use of the pattern paper for the record necessitates the cutting of more papers as one paper is filled, by using both sides of the paper between twenty and thirty parallel records can be made. As the long paper will run a series over an hour and a half long, one paper is good for approximately forty-five hours. By cutting five papers at one time the labor of cutting patterns is considerably reduced. The ease of reading the records also compensates for the extra labor of cutting the patterns. To run one paper for the pattern and another for the record would necessitate some method of ensuring that they ran at exactly the same rate or the devising of some method of marking their correspondence. Reading the record would be less easily accomplished than in the present method.

The apparatus to carry the paper is simple. The paper is wound upon a brass reel and from this passes over a horizontal brass tube 1 inch in diameter with adjustable flanges that guide the paper. Two rollers, constructed from the platen roll of a typewriter, operate to draw the paper along. One of these rollers is held tightly against the other by adjustable springs. The other is turned by a worm reducing gear which is in turn attached by a small shaft to a friction reducing gear. At this point the finer adjustments of speed are controlled. To this reducing gear is attached a $\frac{1}{8}$ h.p., A. C. motor, which is larger than is necessary but is as constant as desired for this work. As the paper passes through the rolls it can be wound on to a second reel ready for transfer to the original position or allowed to run off the end of the table. In our first arrangement platinum was soldered to the brass tube at the positions of the four rows of holes in the pattern paper. Above these were four spring brass contacts tipped with platinum under which the pattern passed. This arrangement caused puzzling difficulties, as frequently the contacts failed entirely or were imperfect. Apparently dust or the fiber of the paper collected and for the brief time allowed for contact produced an effective insulation. After trying various methods to eliminate this defect the sliding platinum contacts were replaced with small wheels of glass cutters which rested directly upon the brass tube when a hole passed under. By exercising care to keep the bearings of these wheels clean, where dust and fiber still collect, the contacts have proved very satisfactory. Mr. Reeves has called our attention to Mr. Jones' solution[4] of the same difficulty in a similar apparatus at the laboratory of the Eastman Kodak Company by a more ingenious method and has kindly offered assistance in the construction of a contact maker along similar lines that would meet our needs. At present, however, the simpler design seems to meet our requirements satisfactorily. It is seldom that a contact misses or is defective.

DISTRACTION TESTS

Our earlier experiments in fatigue indicated that frequently disturbances during the test would appear to have a beneficial effect rather than to operate as a distraction. The question arose whether this would be true if the distractor were continuous throughout the test and, if so, whether it would be the same for all subjects. Morgan[5] has shown, since Miss Berger's work was begun, that a continuous distraction may be overcome and that it is overcome by the expenditure of greater energy. Cassel and Dallenbach,[6] by the introspection method, conclude that the distraction may work either way, but that the intermittent distractor is the most resistant to habituation.

---

[4] Jones, L. A., A new non-intermittent sensitometer, Jour. of the Franklin Institute, March, 1920.

In Miss Berger's experiments two types of distractions were used, an electric buzzer placed 10 feet from the subject and a weak induction shock administered to the left forearm. The buzzer was tuned to produce a clear, fairly intense noise. As it was placed 10 feet to the side of the subject while the sounders to be discriminated were in a small box on the table about 2 feet in front of the subject, it was assumed there would not necessarily be any confusion of the noise with the click of the sounders, except that due to distraction. For the induction shock a small copper plate bound to the forearm with a broad rubber band served as one electrode. The other electrode, a short brass cylinder, was held in the left hand. Unfortunately both of these distractors varied considerably in intensity. In a few instances the induction shock would become so intense as to be decidedly painful with extreme contraction of the muscles stimulated. The results, therefore, fall into two classes, with continuous and intermittent distractors.

Two tests constituted a days series, a normal test of twenty minutes followed twenty minutes later by a twenty-minute test with distraction. Usually the order was reversed on alternate days. The apparatus was adjusted to present one sounder click every second. The signals occurred at the beginning of each second. In each four minutes each sounder was signaled, though not always in the same order. The subject was seated in a relatively quiet room. The contact apparatus was set up

---

[5] Morgan, J. J. B., Overcoming distractions and other resistances, Arch. of Psych., 1916, no. 35.

[6] Cassel and Dallenbach, The effect of auditory distractions upon sensory reaction, Amer. Jour. of Psych., 1918, xxix, 129–143.

TABLE 1

SUBJECT	ORDER	NORMAL			DISTRACTION			RATIO	REMARKS
		Omissions	Error	Total	Omissions	Error	Total		
		per cent	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*		
A.	N–D	41	16	57	46	23	89	151	Current aided; easier to attend
	D–N	69	28	97	62	27	89	92	Current very strong; arm jerked
	N–D	44	10	54	49	12	61	113	Current strong; screamed and shook
	D–N	49	24	73	51	21	72	99	Current moderate
	N–D	18	10	28	29	8	37	132	Intermittent, but not so distracting
	D–N	37	10	47	23	6	29	62	
	N–D	46	10	56	43	4	47	84	
	D–N	54	22	76	54	18	72	95	
Average.......		45 (44)	16 (19)	61 (63)	45 (46)	15 (16)	62 (59)	103 (107)	
Br.	N–D	31	12	43	11	8	19	44	Buzzer, moderate intensity
	D–N	6	4	10	11	5	16	160	Buzzer, moderate intensity
	N–D	12	5	17	4	5	9	53	Buzzer, moderate intensity
	D–N	26	12	38	23	12	35	92	Buzzer too loud, obscured stimulation
Average.......		19 (19)	8 (8)	27 (27)	12 (14)	8 (8)	20 (22)	82 (102)	
Br.	N–D	22	3	25	20	4	24	85	Induction current as distractor
	D–N	20	3	23	19	2	21	91	Induction current as distractor
	N–D	17	5	22	24	3	27	122	Induction current as distractor
	D–N	38	5	43	39	3	42	98	Induction current as distractor
	N–D	14	4	18	12	2	14	78	Induction current as distractor
Average.......		22 (26)	4 -(4)	24 (31)	23 (26)	3 (3)	26 (28)	95 (100)	

Bu.	N-D	3	2	5	8	3	11	220	Buzzer; did not bother; fatigued at end
	D-N	14	5	19	28	4	32	168	Current; bothered only when irregular
	N-D	20	8	28	20	6	26	93	Current; bothered only when too intense
	D-N	10	8	18	10	7	17	95	Current; feeling of strain
Average.......		12 (12)	6 (5)	18 (17)	17 (19)	5 (5)	22 (22)	144 (157)	
Do.	N-D	37	13	50	27	11	38	76	Buzzer; grew monotonous
	D-N	27	17	44	26	16	42	95	Current
	N-D	40	24	64	27	18	45	70	Current; strong; contracted muscles
	D-N	47	24	71	45	20	65	92	Current
	N-D	33	15	48	30	9	39	89	Current
	D-N	21	11	32	9	3	12	38	Buzzer; not noticed
	N-D	26	16	42	13	23	36	86	Buzzer; distracted; greater effort involved
	D-N	22	12	34	15	8	23	68	Current; painful and distracting
Average.......		32 (34)	17 (18)	48 (52)	22 (27)	14 (13)	38 (39)	77 (67)	
Do.	D-N	25	12	37	24	6	30	81	Current
	N-D	42	15	57	24	8	32	56	Current; intense; attention divided
	D-N	10	4	14	27	5	32	229	Current; talking in hall disturbed normal test
	N-D	20	3	23	22	4	26	113	Current; tests seemed more difficult
	N-D	30	9	39	19	2	21	54	Current
	D-N	29	6	35	20	7	27	77	Current
Average.......		26 (26)	8 (9)	34 (36)	23 (23)	5 (5)	28 (27)	102 (141)	

TABLE 1—*Continued*

SUBJECT	ORDER	NORMAL			DISTRACTION			RATIO	REMARKS
		Omissions	Error	Total	Omissions	Error	Total		
		per cent	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*		
F.	N-D	35	35	70	27	32	59	84	Buzzer; forgot all about it
	D-N	40	25	65	61	41	102	157	Buzzer; bothered at first, but adapted
	D-N	42	21	63	45	18	63	100	Current
	D-N	44	7	51	38	6	44	86	Current
	N-D	38	8	46	28	7	35	76	Current; easier than normal test
	N-D	40	8	56	28	2	30	63	Current confusing
	D-N	21	5	26	37	7	44	169	Current
	N-D	20	5	25	29	9	38	152	Current
	D-N	28	5	33	37	7	44	133	Current
	N-D	29	8	37	27	8	35	95	Current
	N-D	15	2	17	11	2	13	77	Current
	D-N	22	3	25	11	1	12	50	Current
Average......		31 (30)	11 (19)	43 (44)	32 (36)	12 (21)	43 (57)	103 (110)	
L.	N-D	17	2	19	16	1	17	89	Current prickled, but did not bother
	D-N	6	1	7	7	1	8	114	Current
	N-D	16	4	20	14	3	17	85	Current very severe; distracted at times
	D-N	24	5	29	23	5	28	96	Current
	N-D	3	0	3	9	1	10	333	Current
	D-N	8	1	9	10	2	12	133	Current
	N-D	11	1	12	11	1	12	100	Current
	N-D	14	2	16	15	4	19	119	Current
	D-N	19	3	22	16	2	18	82	Current. Attention better in normal
	N-D	10	1	11	11	1	12	109	Current. Easier with distractor
	D-N	10	3	13	9	3	12	92	Current
Average......		14 (14)	2 (2)	15 (19)	13 (15)	2 (3)	15 (19)	123 (208)	

in the adjoining room. This was not absolutely isolated from the subject's room, but what sound there was, was uniform throughout the entire series. The subject was instructed to select the sound signaled and react by pressing the key every time this one occurred. After one minute a second signal would be given and so on. Two types of failure are possible. Either he fails to react to the proper sound, termed "omissions" in these results, or he may react to the wrong sound, termed "error" for convenience. As five seconds were required for the signal, the subject, to make a perfect score, would react fourteen times per minute. All the subjects, except Miss Berger and the writer, were advanced undergraduates in psychology. All knew in a general way the nature of the experiments, but were instructed to take a neutral attitude and do their best under all conditions. As there was no way for a subject to know or estimate how well he was doing, the element of rivalry was fairly well eliminated. The lack of knowledge of performance is an important feature with some disadvantages.

Discussion of results

The results are summarized in table 1. In the second column the order of the two daily tests is indicated, as normal followed by distraction (N-D). Under per cent omissions is given the per cent of times the subject failed to react to the correct sound and under per cent error is recorded the per cent of reactions to the wrong sounds. As there are three times as many possibilities to react to the wrong sounds, this per cent is based upon the corresponding number. The sum of these two columns is given under "total per cent." The ratios of the results with distraction to the results with normal conditions were determined by dividing the total per cents of failures under distraction by the total per cents of failures under normal. As all results in this series of experiments represent failures, if the ratio is above 100, it represents that the subject made a poorer showing under distraction than under normal. The average of the results is given at the bottom of each column. As there are so few results for each subject, the average of the extremes instead of the average deviation, is given as a check upon the average. In the last column are given such data as were available regarding the conditions of the test and introspective reports of the subjects. As remarked above, it has been impossible to find all the data concerning each test.

It will be seen that the results present no constant tendency. The average ratio for A. is 103, though five of the nine tests would indicate that she did better with the distraction than with the normal. One might assume that in this case the order of the tests influenced the results. The poorest showings are made when the distraction test follows the normal. From previous experience with the sounder test we would expect the results of the second test to be better than in the first, due to practice effect. It does not seem probable that the order of the tests has played a significant part in this case. There is also little agreement between A's introspections and the results. In the first tests the distraction seemed to make the test easier, though she did 51 per cent more poorly than in the normal test. In the next day's work the current was so strong that it caused involuntary twitching of the muscles. Yet the test with distraction is slightly better than in the normal. On the fifth day the introspections and results again disagree.

Br.'s results are divided into two groups, because they were secured in separate years, the first set with the buzzer and the second set with the induction shock. In both groups, except for a single exception in each, there is marked superiority with the distraction. The results of Do. were also divided according to years. The first group shows consistent superiority with distraction, though the second group is more ambiguous. The other subjects show considerable variation, which seems to bear no relation to their own judgment of their performance, unless it is a contradictory one. A summary of the results and the available introspections indicates two facts; first, in the great majority of cases the subject wrongly estimates his performance and the influence of the distraction and second, he frequently indicates, directly or indirectly, that greater effort was involved.

This points to an important weakness in this and similar types of test for the study of fatigue and allied conditions, to which we will return after discussing further experiments with the sounder test dealing with mental fatigue.

MENTAL FATIGUE

The procedure in these experiments was similar to that already described, except that two tests of fifteen minutes each were given, separated by an interval of one hour. On one day the subject was permitted to rest this hour. No specific instructions were given regarding the employment of this time other than that he must not apply himself to any continuous task, such as study, writing letters or serious discussion. He might read the morning paper providing he did so with an indifferent attitude. The aim was that the rest period should not cause ennui, but should be a genuine relaxation. An equal number of periods were filled with strenuous mental exercise of a controlled type. Ordinary problems in addition and multiplication were considered unsatisfactory as this type of exercise too nearly resembles the usual work of the average student. We would hardly expect a marked effect in one hour. Accordingly we adopted addition from dictation. A pendulum was set to swing once a second, a little slower for the poorer subjects and somewhat faster for one, Bm. The writer could see the swinging pendulum by indirect vision and dictate single digits clearly and sharply with each swing of the pendulum. After the tenth digit one swing was omitted and the subject was to report the sum. The next series was started on the next beat whether the subject had reported or not. If he became confused and unable to finish the series, he was to report "lost" at once and a new series would be started. This prevented the possibility of resting through the remainder of the series, though it prevented an accurate score of the number of correct additions for sections of the period, as the number of problems would vary slightly. There was no doubt that the task was trying and each subject seemed to take the attitude that this was something that he particularly would be poor in. Consequently each appeared to work at his maximum. There

TABLE 2

SUBJECT	OMISSIONS	ERROR	TOTAL FAILURE		OMISSIONS	ERROR	TOTAL FAILURE	RATIO
	per cent	*per cent*	*per cent*		*per cent*	*per cent*	*per cent*	
Bk.	58	14	72	Rest 1 hour	40	15	55	76
	35	9	44	Rest 1 hour	36	12	48	92
	56	14	70	Rest 1 hour	36	11	47	67
	46	15	61	Rest 1 hour	35	12	47	77
Average...	49 (46)	13 (12)	62 (58)		37 (38)	13 (13)	49 (51)	78 (80)
Bk.	48	10	58	Addition by dictation 1 hour	49	17	66	114
	44	13	57	Addition by dictation 1 hour	52	15	67	118
	39	8	47	Addition by dictation 1 hour	64	12	76	161
	45	10	55	Addition by dictation 1 hour	54	14	68	124
Average...	44 (44)	10 (11)	54 (57)		55 (57)	15 (15)	69 (71)	129 (138)
Bm.	26	10	36	Rest 1 hour	28	16	44	122
	21	17	38	Rest 1 hour	17	18	35	92
	22	6	28	Rest 1 hour	13	6	19	68
	18	3	21	Rest 1 hour	18	6	24	114
	13	2	15	Rest 1 hour	13	4	17	113
	20	5	25	Rest 1 hour	23	4	27	108
	25	6	31	Rest 1 hour	24	8	32	103
Average...	21 (20)	8 (10)	28 (27)		19 (21)	9 (11)	28 (31)	103 (95)

Bm.	27	21	48	Addition by dictation 1 hour	22	18	40	83
	12	10	22	Addition by dictation 1 hour	16	18	34	154
	9	2	11	Addition by dictation 1 hour	6	1	7	64
	8	5	13	Addition by dictation 1 hour	12	3	15	115
	14	4	18	Addition by dictation 1 hour	19	5	24	133
	26	7	33	Addition by dictation 1 hour	34	7	41	124
	20	6	26	Addition by dictation 1 hour	15	4	19	73
Average...	17 (18)	8 (12)	24 (30)		18 (20)	8 (10)	26 (24)	108 (109)
De.	44	10	54	Rest 1 hour	41	10	51	94
	40	11	51	Rest 1 hour	36	12	48	94
	36	8	44	Rest 1 hour	42	10	52	118
	24	7	31	Rest 1 hour	25	9	34	110
Average...	38 (34)	9 (9)	45 (43)		38 (34)	10 (11)	46 (43)	104 (106)
De.	43	12	52	Addition by dictation 1 hour	45	10	55	100
	38	10	48	Addition by dictation 1 hour	34	5	39	81
	33	8	41	Addition by dictation 1 hour	36	8	44	107
	26	7	33	Addition by dictation 1 hour	26	5	31	94
Average...	35 (35)	9 (10)	44 (43)		35 (36)	7 (8)	45 (43)	96 (94)
Sl.	33	6	39	Rest 1 hour	36	8	44	113
	44	10	54	Rest 1 hour	46	10	56	104
	38	10	48	Rest 1 hour	15	4	19	40
	32	8	40	Rest 1 hour	19	5	24	60
	42	13	55	Rest 1 hour	43	13	56	105
Average...	39 (38)	9 (10)	47 (47)		32 (31)	8 (9)	40 (38)	84 (77)

TABLE 2—*Concluded.*

SUBJECT	OMISSIONS	ERROR	TOTAL FAILURE		OMISSIONS	ERROR	TOTAL FAILURE	RATIO
	per cent	*per cent*	*per cent*		*per cent*	*per cent*	*per cent*	
Sl.	23	5	28	Addition by dictation 1 hour	43	17	60	214
	41	10	51	Addition by dictation 1 hour	62	15	77	151
	21	6	27	Addition by dictation 1 hour	32	7	39	145
	36	11	47	Addition by dictation 1 hour	51	15	66	140
	29	10	39	Addition by dictation 1 hour	48	13	61	156
Average...	30	8	38		47	13	61	161
	(31)	(8)	(39)		(47)	(12)	(58)	(177)

were no possible gaps for rest and the work never grew automatic, save possibly for Bm.

Discussion of results

An examination of table 2 will indicate that the rest and work periods have not had a uniform effect with each of the four subjects. A personal acquaintance with these subjects explains in part the variations in their results, though this explanation should be accepted with due caution. It is given here to point out certain characteristics of the sounder test as a measure of fatigue and at the same time to show the different influence of incentive and distraction with different subjects. Bk. has uniformly improved after rest and decreased in efficiency a proportionate amount after work. She was a senior with a high intelligence score on the army test, but with a decidedly "emotional temperament." Whether this was due to training or might be considered of physical origin is doubtful. Her habits of study, sleep and eating were decidedly irregular. These series of tests were the most controlled periods of her life at the time. She was a willing subject. The rest periods were spent in complete relaxation much to her benefit and the conditions of the work periods were faithfully observed. The fall in efficiency during the adding was particularly marked, while her behavior and report indicated that the rest periods had been beneficial. In the case of this subject the tests seem to give a fair measure of the efficiency under the two conditions.

The second subject, Bm., was an entirely different type. He was a telegraph operator working nights from 11 p.m. to 7 a.m. and carrying regular work in the university. He graduated cum laude. His principal characteristics were an unusual ability to go without sleep and an uneasiness when not at work. The tests were run every day at 8:30 a.m. during the summer vacation. The rest periods were not as completely occupied in relaxation as would be desirable or as was the case with the other subjects. He was easily disturbed by his own failures or what he considered failures, by worry concerning the apparatus, in which he took a personal interest or by college affairs which by chance might be brought to his attention just before coming to the laboratory. If the disturbance was in any way connected with the experiment it brought greater effort to succeed. On two occasions he lay down upon the table for a part of the rest period. When he did this, he more completely relaxed. It will be noted that with these two exceptions, the second and third rest days, his record is slightly poorer in the second tests. He was the most efficient adder and reached the limit of the dictator's endurance in dictating clearly for the hour period. He frequently claimed that he could rest between digits. On three occasions he improved in the second tests following work while in three he showed marked deterioration.

The third subject was less reliable so far as performance was concerned. The impression persisted that she might at any time violate the conditions of the experiment. On two occasions results were discarded for such reasons. Her errors were those of a naïve subject rather than of willful fraud. With the most careful control of her work the results presented were obtained. It will be noted that, while there are irregularities that render the results equivocal, the tendency is in favor of better performance following the work periods. She took especial interest in the addition and assumed the attitude that it would indicate inferiority to show signs of fatigue. This was her chief interest in the experiment. So, though she took a pleasant attitude of willingness to coöperate, the chief incentive was the desire to succeed well with the adding and perform normally in the test following. Her attitude regarding the other tests was characterized by more indifference.

Sl. was the opposite of Bm. She was in poor health and she had been trained to capitalize it. Every assignment was viewed as an occasion for another breakdown. She coöperated willingly in the experiment, however, though she was easily disturbed by outside influences. The patter of rain against the window in one test, not shown here, caused a noticeable drop in the record. Other disturbances which the other subjects seemed to disregard were reported as interfering with her performance. Considerable difficulty was also experienced in securing a whole hour of addition. The interval between digits was finally increased to two seconds. It will be seen that the decrease in efficiency following the work period was enormous. It is our conviction that this subject, due to poor training and ill health, is incapable of resisting a slight degree of fatigue, but that the chief cause of the deficiency is due to the incapacity of concentration under any form of distraction. All the class room observations justify the same conclusion.

DISCUSSION OF THE SOUNDER TEST

In considering the results of the sounder test certain factors should be kept clearly in mind. First, the subject has a simple task to perform. He is to select the proper sound signaled and press the key every time this sound occurs. It is not necessary to attend to the other sounds. In fact most of the subjects seem to neglect entirely these sounds and occasionally at the end of the test two of them were omitted without causing any disturbance. In the second place, the subject is practically ignorant of his success or failure. He knows that the signaled sound will occur about fifteen times in the minute and, if he has not reacted as many times, that he must have omitted some. However, he usually makes some wrong reactions which makes counting ineffective. None of the subjects succeeded in improving his interest by counting and the method was soon dropped. In no case was the subject able to judge adequately regarding his total performance.

Due to simplicity of the test a subject is able to isolate the task and make a good record even under unfavorable conditions in spite of the fact that the test is one of continuous discrimination sufficiently difficult to demand serious concentration. Frequent readjustment of the sounders makes it impossible to compare accurately the performances of the several subjects in their ability in the normal tests, though a glance at tables 1 and 2 will show that there is considerable individual difference in normal performance. This should indicate that this test makes some type of demand upon the subject.

The chief value of the sounder test seems to be the determination of the ability of the subject to maintain his standard of performance when affected by other stimuli. These may act as distractors for some and as incentives for others, when associated in some way with the test situation. Though a subject may be placed on the basis of his total performance in several tests, in either of these two groups, he still may show considerable variation from day to day. This may indicate a varying ability of adjustment to the conditions or a variation in the conditions of the test.

Modification of the sounder test

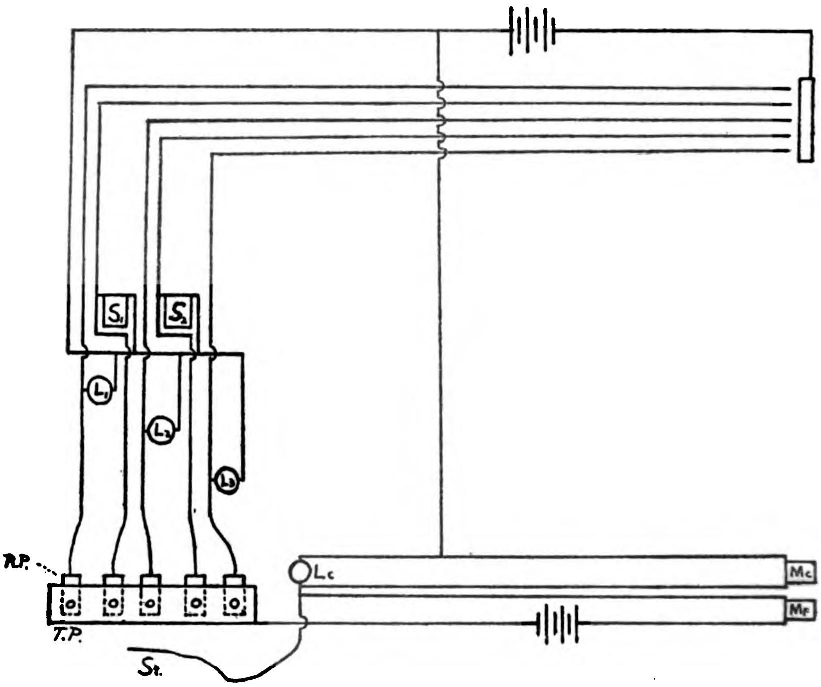
Simplicity of the sounder test has been demonstrated to be the defect that renders it inapplicable for experiments to determine the direct effects of various kinds of work or other factors that might be expected to decrease the efficiency. The apparatus devised by Dunlap[7] and his associates for the psychological test in connection with the low oxygen experiments in the Air Service Medical Research Laboratory suggested the possible solution of the difficulties involved. It will be recalled that in this test there were three objects of attention with a different type of reaction for each. A bank of fourteen lamps must be constantly observed and when one flashes, every three to five seconds, the subject is to touch the corresponding target with the stylus. At the same time a small motor produces a sound of definite pitch. If this pitch suddenly rises, he is to shift it back to "low" by means of a foot switch. The third task is to observe as constantly as possible the indicator hand of a small voltmeter and maintain it at a designated point by manipulating a slide rheostat with the right hand, when not reacting to a lamp. For the purpose for which it was designed this arrangement proved satisfactory. Numerous simpler tests failed. The principal defect for work demanding more definite quantitative measurement was the lack of any satisfactory means of registering a simple objective record.

---

[7] Bagby. English, The Psychological Effects of Oxygen Deprivation, Jour. Comp. Psych., 1921, i, 97–113.

We required an apparatus that would demand a broader attention span than the sounder test and at the same time would produce a quantitative record independent of the experimenter's own judgment. To meet this requirement a combination of sounders, lamps and stylus was arranged. The four sounders originally used were placed in a box 12 inches wide, 18 inches long and 6 inches high. The front of the box slanted back about 30 degrees. In the center of this front was cut a window 1 inch square with beveled edges, and fitted with an opal glass. Through the center of the box, back of the window, were arranged three 3.8 volt electric bulbs, one fixed and the others adjustable with respect to distance from the window. The base of the box, $\frac{3}{8}$ inch thick, extended in front 5 inches and was raised from the table $\frac{1}{2}$ inch by cleats at each end. On the front projection was fastened a brass plate 7 inches long, $1\frac{1}{2}$ inches wide and $\frac{1}{16}$ inch thick. In the plate were five holes $\frac{1}{4}$ inch in diameter and $1\frac{1}{2}$ inches apart from center to center. Larger holes were cut through the base beneath the holes in the upper plate and removable plates adjusted under these holes. The accompanying diagram indicates the connections. The removable plates, R.P., were each connected with a sounder, S_1, S_2, or a lamp, L_1, L_2, L_3, in such a way that if the proper plate were touched with the stylus, *St*, while the current were flowing through the lamp or sounder, a lamp, *Lc*, to the right of the top plate would flash and the electric marker, M_c, at the contact apparatus (p. 2 to 4) would record the contact. If the top plate were touched with the stylus at any time, a second marker, M_t, at the contact apparatus would record. As arranged any combination of the four sounders and the three lamps could be used and the corresponding holes in the plate shifted as desired. In the preliminary tests two sounders and two lamps were used, but it was found that two sounders and three lamps was more satisfactory for the purposes of these experiments.

In order to ensure constant light at the subject's table, the apparatus was set up in a dark room and lighted by a ceiling lamp that gave a little over four foot-candles of light at the subject's table. A shade was arranged above his head that would protect the window from the direct rays. The subject was always allowed five minutes to become adapted to this light. The contact apparatus was set in the adjoining room. Though the hum of the motor could be distinctly heard in the subject's room, this noise was constant in all experiments. The experimenter exercised great care that no other noise connected with the running of the apparatus should occur. Noises from other parts of the laboratory were not noticeable. At certain periods of the day the campus bell, a church bell and train and factory whistles were decidedly annoying to the experimenter, though in this series of tests the subjects were not so frequently disturbed as in the series with the sounder test.



The new arrangement required five rows of holes in the paper of the contact apparatus. In order to lengthen the duration of the contact to allow the subject time to react the holes were cut lengthwise of the paper. Twenty-four holes were allowed to one foot of paper, but this time the holes were irregularly spaced in the rows to avoid the possibility of rhythm of reaction. Each row contained approximately the same number of holes in any longer section of paper, though the number in any 1 foot might vary. The rate of presentation varied with the subject tested, though for most of those presented here the rate was 1 foot (twenty-four holes) in fifty seconds. This rate was later increased to forty-five seconds and in the case of one subject, Bm., to forty seconds.

In order that the reactions should not become automatic the removable plates were shifted before each test. The subject was then given the stimuli, one at a time, and allowed to locate with the stylus the proper hole for each to his own satisfaction. Care was exercised to avoid unusually difficult or easy arrangements of the plates. For example, the plates corresponding to the three lamps would not be arranged together in serial order.

The instructions to the subject were as follows: Hold the stylus much as you would a pencil. (It is advisable to let the hand rest upon the board in front of the plate when not reacting.) When a light flashes or you hear the click of a sounder, react at once by touching the bottom of the proper hole. In this movement the stylus should be held in a vertical position and the hand must be kept free of the board. If you react to the proper hole in the time allotted, the lamp at the right of the plate will flash. If you react too late or to the wrong hole, nothing will happen. Avoid touching the top plate with the stylus (fumble), but do not let this interfere with your reactions to the stimuli. Correct contacts are the essential task; fumbles are relatively unimportant.

Originally a lamp was connected at the left of the top plate which would flash for the fumbles, but it proved to be too slow in flashing to register the lighter fumbles and also tended to emphasize the fumbles more than was desired. The subject usually knows when he fumbles, because of the spark at the point of contact. It will be recognized that this arrangement differs from the original sounder test in several respects and, while it may not seem as complex as the air service apparatus, this is at least partially overcome by increasing the difficulty of discrimination by proper tuning of the sounders and adjustment of the relative position of the three lamps. The time allowed for the reaction is also an important factor. The subject is required to discriminate the stimulus and react at once. Slight hesitation, even to start toward the wrong hole and then deviate to the correct one, will make the contact too late to be recorded. The subject must discriminate both auditory and visual stimuli and react with a definite coördinated movement in a fraction over one second.

It might be objected that this reaction involved an excess of motor coördination and consequently obscured the attention effects. This objection might be admitted were we attempting to determine individual differences of attention ability, but the purpose is to determine the discrimination ability or mental activity of the same subject under different conditions. The results will show that under these conditions the two are inseparable. Even with the simple steadiness test one can not separate the function of attention from the motor control. No systematic recording of data with the steadiness test was attempted with this series, though from time to time the test was made with Do. and Sk. The results were negative so far as any correlation between fumbles and the number of contacts with the steadiness tester were concerned. At one time Sk., after an excessive number of fumbles, reported that he believed his attention was good but that motor control was poor. The steadiness test showed the same number of contacts as on the previous tests when the number of fumbles had been normal. The complicated task of distinguishing the stimulus, selecting the proper reaction and carrying out the correct coördinated movements was a situation preëminently demanding attention.

A further difference between this test and the sounder test was the addition of the lamp to flash correct contacts. While in the sounder test complete ignorance of success or failure was practically maintained, the aim in the new arrangement was to supply in the test all the incentive that knowledge of performance would supply. Though a subject did not know his exact score, he knew when he missed a contact and this would stimulate greater effort, if he was at all interested in the task. By increasing the complexity of the task and increasing the incentive to the maximum the test will more nearly measure the capacity of the subject under any particular conditions. Recognition of interfering conditions, such as fatigue or distractions as in the previous experiments, would not be so capable of increasing the activity of the subject. The correctness of this assumption, we believe, is demonstrated by the results (tables 3–6).

The subjects for these experiments were R. M. Beechley (Be.) and O. O. Bum Garner (Bm.), both graduate students in the department, Margarite Blackford, (Bl.), undergraduate major in psychology, Professor E. B. Skaggs (Sk.) and the writer (Do.). All understood the general purpose of the experiments, but the subject was never discussed with any of the students, nor comparisons made regarding their accomplishments in the tests, except that Bm. and Bl. discovered near the end of the series that they were nearly equal in ability. This seemed to have a slightly stimulating effect for both subjects.

Discussion of results

Tables 3 and 4 contain the following data: Under "correct contacts" are recorded the number of successful reactions made in the fifteen-minute period. The total possible score when the paper travels 1 foot in fifty seconds would be 432 contacts, when traveling 1 foot in forty seconds, 528 contacts. Under "fumbles" are recorded the number of contacts with the top plate. This number is theoretically unlimited. The subject may fumble five or six times in attempting one correct contact or he may hold the stylus against the top plate a shorter or longer time. These differences will be shown by the marker on the record. Each fumble, no matter how short, was counted as one. Longer fumbles were standardized as one, two or three fumbles according to their length. This left room for variations of judgment, but the standard was fairly easily maintained and the writer did all the counting except in his own record. Under "reduced score" we have placed a rather arbitrary value of the total performance. With two scores, correct contacts and fumbles, it is rather difficult to judge just how much difference or similarity in total performance there is in a series of tests. In the instructions the emphasis was placed on correct contacts, yet it would be inadvisable to eliminate the fumbles entirely as they are a product of the total situation. If the total number of possible fumbles bore a definite relation to the number of correct contacts possible, the problem would be simplified. One subject may run a high percentage of fumbles while another runs a relatively low number. If the number of fumbles is small, it might be justifiable to deduct this number from the number of correct contacts, but if it is excessive, this might throw too great weight on fumbles. The method finally adopted to approximate the proper evaluation of fumbles was to determine the ratio of total fumbles in all tests to total correct contacts. This fraction subtracted from one was taken as the value of each fumble to be deducted from the correct contacts. In the last column is given the ratio between the two tests, as in table 2. This is based on the reduced score of each test. It should be remembered that these results represent positive values. Hence a ratio above 100 represents superiority of the second test.

Table 3 represents the results before and after one hour of mental work. The rest periods were under the same controls as those in the sounder tests. This was also true of the work periods that involved addition from dictation. The multiplication consisted in multiplying three place numbers by three place numbers by the cross multiplication method. The directions were to multiply as rapidly and accurately as possible. This method was new to the subjects and required considerable alertness to follow the method and retain the partial product. In two cases private oral examinations were conducted as the mental work. There seemed to be no unusual emotional effect in either case, as both were accustomed to this sort of work and the material covered was that of the advanced class in which they were registered. In one case translation of a scientific article from French into English occupied the hour.

It will be seen that the averages for each subject show the same tendency. Following rest each made more or less improvement and following work each manifested a falling off from the normal records. Furthermore, these changes are constant from day to day for each subject, except for Bm. who manifested a falling off twice after rest and a slight improvement once after multiplication. These exceptions are closely related to the exceptional behavior of this subject in all tests. The improvement following rest may be due to practice effect of the first test or to rest alone or to the combination of the two. Unless we assume a retroactive inhibition resulting from the mental work, we may assume that the practice effect will be equal in both the rest and work series and that the differences in scores are due to the differences in fatigue conditions. The algebraic sum of these differences would represent the difference in capacity at the time of the two tests. The difference in normal scores from day to day may be partly explained by readjustments of the apparatus that were sometimes necessary, but the more important cause was the variability in capacity of the subject. As no attempt was made to preserve exactly the same adjustment of the apparatus throughout the series, it is not possible to gauge exactly the daily variations of the subjects. The variations in adjustment of the apparatus, however, were not sufficient to influence in any way the relative scores on the work and rest days and no change was made between the first and second tests of a single day's series.

Be.'s improvement after rest is due about equally to increased correct contacts and decreased fumbles. After work in all three tests correct contacts have been reduced and fumbles increased. Bl. has shown approximately the same tendency. After mental work fumbles were definitely increased in three of the five tests. Bm. is more irregular, but in general the tendency is the same. Possibly he shows a slightly greater tendency to increase fumbles after mental work than to reduce the number of correct contacts.

Table 4 presents the results of similar tests with rest and physical work interpolated. The work performed by Be. and Bm.

TABLE 3

SUBJECT	CORRECT CONTACTS	FUMBLES	REDUCED SCORE		CORRECT CONTACTS	FUMBLES	REDUCED SCORE	RATIO
Be.	348	183	266	Rest 1 hour	408	102	362	136
	320	148	253	Rest 1 hour	354	148	287	113
	270	266	150	Rest 1 hour	266	244	156	104
Average								118 (120)
Be.	327	198	238	Star examination 1 hour	302	249	190	80
	381	141	318	Multiplication dictation 1 hour	326	217	228	72
	352	235	247	Multiplication dictation 1 hour	336	270	216	88
Average								80 (80)
Bl.	399	191	298	Rest 1 hour	396	119	333	112
	385	151	305	Rest 1 hour	401	150	321	106
	389	236	269	Rest 1 hour	380	129	311	116
	413	308	250	Rest 1 hour	441	222	323	129
	420	273	275	Rest 1 hour	445	208	335	122
Average								117 (117)
Bl.	378	122	313	Star examination 1 hour	376	123	311	99
	404	136	332	Multiplication dictation 1 hour	357	196	253	76
	400	200	294	Multiplication dictation 1 hour	388	216	273	69
	449	226	329	Multiplication dictation 1 hour	414	291	259	79
	448	296	291	Translating French 1 hour	432	289	279	96
Average								84 (84)

Bm.	354	120	270	Rest 1 hour	366	168	248	92
	384	112	306	Rest 1 hour	392	95	325	106
	366	99	297	Rest 1 hour	354	95	288	97
	392	82	335	Rest 1 hour	409	43	379	113
Average								102 (102)
Bm.	379	125	291	Multiplication 1 hour	383	103	311	107
	379	65	333	Multiplication 1 hour	379	78	324	97
	383	112	303	Multiplication 1 hour	331	220	177	58
	399	63	355	Multiplication 1 hour	362	84	303	85
Average								87 (82)
Bm.	383	120	299	Addition by dictation 1 hour	379	120	295	99
	392	73	341	Addition by dictation 1 hour	344	112	266	78
	386	62	343	Addition by dictation 1 hour	358	125	270	78
	409	60	367	Addition by dictation 1 hour	366	90	303	83
Average								80 (88)

TABLE 4

SUBJECT	CORRECT CONTACTS	FUMBLES	REDUCED SCORE		CORRECT CONTACTS	FUMBLES	REDUCED SCORE	RATIO
Be.	303	129	245	Rest 20 minutes	344	84	306	125
	360	222	240	Rest 20 minutes	348	207	255	106
	362	273	239	Rest 20 minutes	354	141	291	122
Average								118 (114)
Be.	358	79	322	Harness 20 minutes	273	185	190	59
	313	100	268	Harness 20 minutes	320	171	243	91
	345	81	309	Harness 20 minutes	283	198	194	63
Average								71 (75)
Bm.	408	56	369	Rest 20 minutes	409	43	379	103
	325	87	264	Rest 20 minutes	404	50	369	140
	381	82	324	Rest 20 minutes	384	84	327	101
	391	72	341	Rest 20 minutes	418	31	391	115
	379	149	275	Rest 20 minutes	382	130	291	106
Average								113 (121)
Bm.	357	84	298	Harness 20 minutes	354	106	280	97
	384	97	316	Harness 20 minutes	366	152	260	82
	399	91	335	Harness 20 minutes	407	89	345	103
	355	131	263	Harness 20 minutes	328	172	208	79
Average								90 (91)

Bl.	453	187	354	Rest 2 hours	456	198	351	99
	427	247	296	Rest 2 hours	459	200	353	119
	457	151	377	Rest 2 hours	461	207	351	93
Average								104 (106)
Bl.	427	303	266	Walk 2 hours	460	215	346	130
	444	190	343	Walk 2 hours	455	211	343	100
	467	173	375	Walk 2 hours	458	161	373	99
Average								110 (114)

was to lift for twenty minutes on the "harness ergograph" described in the earlier report.[8] The subject stands astride a heavy spiral spring which is attached to the floor. Attached to the upper end of the spring is a leather harness which passes over the shoulders of the subject. The shoulder straps are padded with thick felt. The tugs are shortened sufficiently that when the subject is not lifting against the spring he is standing in an awkward squatting position. Standing erect he lifts his maximum. If he lifts as hard as he can every two seconds to the beat of a metronome, there is very little opportunity for him either to rest or "lie down on the job." This has proved a most satisfactory fatigue producing instrument. It exercises a large group of muscles and, either standing or squatting, the subject is in a fatiguing position. The hands and arms are free which leaves them relatively unaffected directly for any manipulation in a test that may follow.

Both subjects show the same tendency following rest and work with a slight exception by Bm. The decrease in efficiency following work is more marked with Be., but both show the influences of the rest and work periods more distinctly than was shown by the subjects under similar conditions with the sounder test in the previous investigation.[9] The results are quite decisive here.

It may be objected that the physical work has caused the deterioration by affecting directly the motor coördination. At first sight this seems true in the case of Bm.'s results, though it is not particularly manifested by Be., but it should be remembered that this tendency to increase fumbles was generally manifested by all subjects following mental work, particularly by Bm.

Three other subjects were used in the physical fatigue tests, but walking at practically their highest speed for two hours was substituted for the harness ergograph. In the case of Bl. the tests were given before and after the rest and work periods, as in the previous experiments (table 4) Sk. and Do. were tested at five o'clock under conditions clearly defined, as it was not possible always to give the test immediately before the period.

---

[8] Op. cit., p. 206–210.
[9] Op. cit., p. 229–234.

The results of Bl. in this particular instance are unimportant, but are given in order that the report may be complete. These tests were given near the end of the semester during a very humid warm week. Bl. had been under more or less of a strain for several weeks and could not be considered in normal condition. Rest and outdoor exercise were what she most needed. While the walks were to be "forced walks," she seemed to fail to carry out this part of the requirement, as she walked only about half the distance in the same time as did the other two subjects. Allowance must be made for the fact that they were men, but, making all due allowances, she still gave evidence of not walking at a "forced" rate. Considering also that she undoubtedly needed outdoor exercise and relief from her usual work, it may be presumed that the walks were beneficial. At any rate the results are equivocal. In two tests following rest she fails at least to increase her record. Also, her greatest improvement was after a two hours' walk. As her results with mental work, secured earlier in the year, conform so definitely to the usual tendency of the other subjects, it may be assumed that the walks were not so fatiguing for her as for the other subjects or that the beneficial effects compensated for the fatigue effects, rather than that her results indicate unreliability of the test. We should expect some subjects to overcompensate in this test, as in the sounder test, but thus far, we believe Bm. is the only one of our subjects who has been able to do so.

The results of Sk. (table 5) were secured under three conditions. The test was given at five o'clock following a day of light work, usually Sunday, a day of relatively exacting work in the laboratory ending with two successive hours of oral quiz sections, and a day of moderate work ending with two hours of forced walk. The dates of these tests are given in order to indicate the tests that should be compared. Normal daily variations will, presumably, partially obscure the effects of the different types of days. Nevertheless, it will be seen that the results indicate fairly definite tendencies. The ratios of the tests following walks and quizzes are based upon the tests on "light" days that are of nearest date. In the case of the test on December 15 the

TABLE 5

SUBJECT	DATE	LIGHT DAY				WALK 2 HOURS				QUIZ 2 HOURS			
		Correct contacts	Fumbles	Reduced score	Ratio	Correct contacts	Fumbles	Reduced score	Ratio	Correct contacts	Fumbles	Reduced score	Ratio
Sk.	11/16/21									300	135	259	88
	11/25/21					299	164	250	85				
	11/27/21	336	137	295	100								
	12/ 1/21									352	141	310	87
	12/ 2/21	394	135	354	100								
	12/ 2/21					313	191	256	83				
	12/ 4/21	358	165	308	100								
	12/ 8/21					268	237	197	74				
	12/ 9/21	327	203	266	100								
	12/10/21					303	312	209	59				
	12/11/21	382	94	354	100								
	12/14/21	389	161	341	99								
	12/15/21									331	248	256	74
	12/17/21	402	181	348	101								
	4/ 7/22									330	390	213	66
	4/ 8/22					366	490	219	68				
	4/ 9/22	426	340	324	100								
	4/14/22									354	426	226	70
	4/15/22					310	523	153	47				
	4/22/22					347	372	235	70				
	4/23/22	434	331	334	100								
Average......					100				69 (66)				77 (77)

ratio is based on the average of tests on December 14 and 17. As this subject maintained a definite daily schedule, his results may be compared with considerable degree of accuracy. It will be observed that on the work days, whether we consider the tests following forced walks or quizzes, he showed a marked deterioration in performance. This is slightly greater following the walks. The least decrease is 15 per cent while the greatest decrease is 53 per cent after walking. The least decrease after quiz is 22 per cent and the greatest is 34 per cent. The number of fumbles has increased in every test after walking and in every test after quiz except in the one on November 16. On the other hand the number of correct contacts has been reduced in every test following either type of work day.

TABLE 6

SUBJECT	DATE	CORRECT CONTACTS	FUMBLES	REDUCED SCORE	RATIO	CONDITIONS AT TIME OF TEST: 5 P.M.
Do.	3/26/22	296	228	182	82	After 2 hours forced walk
	3/28/22	341	237	223	100	After easy day
	3/30/22	348	160	268	120	Rather tired; after reading quis papers
	4/ 4/22	338	305	186	53	After 2 hours forced walk
	4/ 6/22	355	164	273	78	Fatigued; laboratory work all day
	4/11/22	413	123	352	100	After very light day
	4/12/22	328	196	230	65	After 2 hours forced walk
	4/13/22	358	194	261	74	Mildly fatigued
	4/17/22	419	127	356	102	Heavy day, but not particularly fatigued
	4/18/22	349	176	261	75	After 2 hours forced walk
	4/25/22	418	140	348	100	Very light day; good condition
	4/27/22	415	147	342	98	Moderately easy day; no fatigue
	5/ 1/22	350	115	293	84	After 3 lectures
	5/12/22	376	189	282	84	After 2 hours forced walk; hot day
	5/16/22	413	155	336	100	After easy day; no work in afternoon

The conditions under which the tests were given to Do. (table 6) were not so definite in all cases as for Sk. We have, therefore, arranged the results in slightly different form and stated as clearly as possible the conditions under which the tests were given. The ratios are based on the tests following days in which little or no work was done. The separations in the table will indicate the groups for comparison. The performance following the walks is in every case inferior to that on the light days. Laboratory work and lectures show approximately an equal decrease. On three days the results of the tests and the reports of the subject do not agree in showing the same tendency. On March 30, after a relatively easy day, two hours were spent in reading quiz books. "Mildly fatigued" may here imply that the subject was merely bored. On April 13, after a moderate day, he reports that he is only mildly fatigued, but the results would indicate that he was as fatigued as on the days of heavy work. However, on the days when the work was definitely easy or difficult, the results were unequivocal. Doubtless the daily variations in efficiency of this subject were great enough to obscure the milder fluctuations in the day's work.

The number of fumbles after walking were increased in four of the five tests, while after work in the laboratory and lectures fumbles have been increased slightly in three tests and reduced in one. Correct contacts have been reduced in every test following either type of definitely defined work.

Diurnal variations

In table 7 are given data not so much to demonstrate the validity of the test as to apply the test to the investigation of diurnal variations. The results are meager, save for one subject, but it seemed worth while to present them here. The tests were given as nearly as possible at the times indicated. The daily schedule of Sk. was quite uniform, that of Do. varied considerably, while that of Bm. can not be compared with the others in any way. It will be remembered that he was employed as telegraph operator from 11p.m. to 7 a.m. He reported at the laboratory regularly at 8:30 a.m. The second and third tests were at the times indicated. The fourth test was at 3:30 or 4:00 p.m., immediately before he went to his room to sleep. What is really the beginning of the work day for the others is the end for him. The ratios are based in every case on the results of the first morning test. The separations indicate the groups to be compared.

It will be seen that Sk. quite uniformly shows his greatest efficiency at the eleven o'clock hour and his poorest at one o'clock. This was contrary to his own estimate. His common remark at the morning test was, "a good night's rest and feeling fit for a day's work." He believed this was the best time of the day for him to accomplish work. It would appear that he gradually warms up to his work during the forenoon. The same course is repeated in the afternoon, but starts lower and never rises to the eleven o'clock standard. There is a little drop again at nine o'clock. Whether the falling off in efficiency at one and nine o'clock is due to the interference of digestive functions, further investigation is needed to determine. Sk. believed that the one o'clock test suffered from inhibitions set up by the test immediately preceding, as these tests occurred closer together than the others. It will be recalled that the holes corresponding to the stimuli were shifted at the beginning of each test. His assumption, however, is not borne out by the results. On three days the one o'clock test was given when the eleven o'clock test had been omitted. The results of two of these tests conform to the usual tendency. The third, February 9, is somewhat irregular all day. It is probable that inhibitions had little to do with the big slump at the one o'clock test.

The data for Do. is not so complete, but the general tendency is somewhat similar. On the whole his best performance may be considered to be at eleven o'clock. The data at one o'clock are insufficient for definite determination, but we may consider that there is a gradual falling off until 4:30 p.m. Two of the nine o'clock tests give relatively high scores, while the third reverses the tendency. These results in general agree with the subject's work. The forenoon is considered his best work period with a decided slump in the afternoon. If the work of the day has been light, the evening is a better work period than the afternoon, according to his own estimate.

The data of Bm. are too inadequate to show any tendency, except possibly the tendency already referred to, namely, that he in all tests showed an exceptional capacity for resisting fatigue or distraction. This is strikingly shown in his results of March

TABLE 7

SUBJECT	DATE	8 A.M.				11 A.M.				1 P.M.				4.30 P.M.				9 P.M.			
		Correct contacts	Fumbles	Reduced score	Ratio	Correct contacts	Fumbles	Reduced score	Ratio	Correct contacts	Fumbles	Reduced score	Ratio	Correct contacts	Fumbles	Reduced score	Ratio	Correct contacts	Fumbles	Reduced score	Ratio
Sk.	12/ 2/21	329	257	257	100	344	194	286	111	293	167	243	94	394	135	354	137				
	12/ 4/21	274	152	288	100									358	165	308	107				
	12/ 9/21	385	192	327	100									327	203	266	81				
	12/10/21									299	251	228	69								
	12/14/21	278	274	196	100									389	161	341	173				
	12/17/21					390	218	325	166					402	181	245	125				
	12/18/21					361	355	254	139	293	412	152	77								
	1/10/22	363	363	254	100	392	179	338	133	278	332	178	70	374	214	310	122	342	184	287	109
	1/17/22					369	264	290	120	293	399	174	75	393	244	320	138	372	203	311	134
	1/18/22	321	297	232	100																
	2/ 9/22	348	252	272	100					361	173	309	114	373	213	309	114	357	235	256	94
	2/16/22			(291)	(100)	353	258	276	95	369	243	296	102	347	198	288	99	369	245	295	101
	2/23/22	370	202	309	100	373	177	323	105	335	312	241	78	397	210	334	108				
	3/ 2/22	350	217	285	100	371	183	316	111	315	291	228	80	383	206	321	113				
	3/ 9/22	382	199	322	100	397	176	344	107	288	300	198	61	369	213	305	95	337	316	242	75
	3/16/22	370	197	311	100					352	235	282	91	277	375	164	53				
Average.............					100				121 (131)				83 (88)				113 (113)				103 (105)

Do......	1/10/22	268	21	163	100	290	122	229	140	287	107	233	143					364	128	300	184
	1/17/22	294	94	200	100					262	94	168	84	272	108	214	107	337	135	269	134
	1/18/22	336	147	263	100									297	130	232	88				
	3/16/22	276	155	199	100	352	111	297	149					321	188	227	114				
	3/30/22					340	128	276	139	271	82	230	121	348	160	268	135				
	4/ 6/22	368	194	271	100	370	213	263	97					355	164	273	101	340	218	231	85
	4/13/22					400	137	332	101					358	194	261	79				
	4/15/22	409	161	329	100																
	4/17/22													419	127	376	114				
	4/20/22	395	172	309	100	384	154	305	99												
	4/27/22	375	188	281	100	391	143	320	114					415	147	342	122				
Average..............					100				120 (123)				116 (113)				108 (107)				134 (138)
Bm......	2/ 7/22	450	162	337	100	438	212	289	86	453	219	300	89	446	224	289	86				
	2/10/22	467	158	356	100					505	124	424	119	494	190	361	102				
	2/21/22	445	171	325	100	427	213	278	86	453	211	305	94	451	191	317	98				
	3/13/22													481	130	390	100				
	3/14/22	485	137	388	100					454	189	322	83								
Average..............					100				86				96 (101)				97 (94)				

13. He had not worked Saturday night, but had gone out of town to visit relatives, returning in time to take up his work Sunday night without sleep. After a busy night and a normal day of class work, he came to the laboratory at 3:30 for the test. He had been thirty-six hours without any sleep and eighty-six hours with a total of ten hours sleep variously distributed in the previous fifty hours. His score on this test was as good as at any time on the preceding or following day. Judging by the total results his performance is only slightly poorer later in the day than it is at 8:30 a.m.

CONCLUSIONS

Only a few tests have been given to any one subject under a given condition, but the results are so uniform for all subjects that it is believed the following conclusions are justified:

1. The sounder test is a severe test of ability to attend to a single stimulus or discriminate slight differences in a group of nearly equal stimuli, but due to the narrow span of attention required, a subject may effectively master the situation under unfavorable conditions. It may be compared to the remarkable feats of sensory discrimination frequently reported in the lower animals.
2. The sounder test is fairly well adapted to determining individual differences in ability to overcome distraction. It may be also adapted to determine individual differences in attention to an auditory stimulus.
3. The modified test makes more general demands upon the subject and at the same time yields relatively simple quantitative results. It differs from McDougall's dot marking test[10] in that it places greater emphasis upon discrimination. At least the process is more complex. The motor coördination involved is much the same. McComas' test[11] required recognition of colors and speed in reaction by pressing the proper key,

---

[10] McDougall, W., A new method for the study of concurrent mental processes and of mental fatigue, Brit. Jour. of Psych., 1905, i, 434–445.

[11] McComas, H. C., An apparatus for recording continuous discrimination reactions, Jour. Exp. Psych., 1917, ii, 171–177.

but does not seem to require the same degree of discrimination or complexity of coördination. Our experience would suggest that the advantage gained in greater complexity of the processes involved would more than compensate for the slight increase in complexity of the numerical results.

4. There was no noticeable fatigue of the sense organs involved. The window was near enough to the plate that both could be held in the field of vision and neither demanded constant fixation, as one would expect with Miles' pursuitmeter.[12]

5. The results with our attention-coördination test have possessed a high degree of uniformity where the conditions could be clearly defined. With rest there was improvement in the score, both in correct contacts and in fumbles; following work, whether mental or physical, the tendency has been consistent with all subjects when the averages of their results are considered and, with the exception of one subject, the individual results of each subject conform to the average.

6. In the sounder test the subjects were continually disturbed by outside distractions, noises in neighboring rooms, etc. In the later test such disturbances were seldom reported. The ringing of the class bell on the campus or the whistle of a near-by train was very seldom reported by the subject. The experimenter recorded all possible disturbances, but rarely did the subject's record show any change at these points. Usually, when questioned after the test, he could not recall having heard them. On one occasion the train whistle, factory whistles and church bell all sounded in one test, but the subject merely reported that he thought a train whistled once. Attention seems to be completely involved in the test.

7. A comparison of the results with these two tests suggests a possible explanation of the results obtained by Miss Smith[13] with McDougall's dotting test. It may be that this test resembles more the sounder test in simplicity and that consequently she was able to overcompensate for the effects of vigil. With

---

[12] Miles, W. R., The pursuitmeter, Jour. Exp. Psych., 1921, iv (?), 77–105.

[13] Smith, May, A contribution to the study of fatigue, Brit. Jour. Psych., 1916, iii, 327–350.

rest the greater inertia involved made this less easy. She may also possess the capacity of Bm. in resisting fatigue or loss of sleep. We would expect with a test demanding the broader span of activity the results would with most subjects fail to conform to her curves of efficiency.

8. If the above conclusions concerning the attention-coördination test are correct, it should prove a satisfactory test for the investigation of the effects of fatigue, low oxygen, ventilation, tobacco and drugs. Whether it can be used for the study of industrial fatigue is more questionable. Further work is now under way to adapt the test to the study of individual differences. If this is successful, the test could be used for the examination of candidates for the air service and other professions demanding similar capacities.

THE EFFECTS OF CIGAR AND CIGARETTE SMOKING ON CERTAIN PSYCHOLOGICAL AND PHYSIOLOGICAL FUNCTIONS[1]

ROBERT LEE BATES

From the Psychological Laboratory of the Johns Hopkins University

I. DART THROWING

1. *Apparatus and methods*

In preliminary work on the effects of tobacco smoking on accuracy in dart throwing,[2] Carver found indications that smoking caused a decrease in accuracy of throwing, within a short period after the smoking. On account of the relative smallness of the indicated effect, and the negative results of tests on certain other functions under smoking conditions, it was important that this evidence should be fully checked by further work.

The work here reported was accordingly undertaken in the Fall Semester of 1920 under Professor Dunlap's direction. The apparatus (targets and darts) used by Carver was employed. The "Apex" darts (see fig. 9) were the same as those used by Buford Johnson in her original dart-throwing experiment,[3] but the target was Dunlap's modification of Johnson's target.

The target foundation consisted of seasoned wood upon which was glued sheet cork of 1 inch in thickness and 3 feet square. The cork made an excellent medium for the penetration of the points, as the darts could be easily removed, and owing to its pliability, the deterioration of the backing was reduced to a minimum.

---

[1] The expenses of this research were in part defrayed by the committee to study the tobacco problem, but the responsibility for the planning and execution of the work, and for the conclusions, rests solely with the author and Professor Dunlap.

[2] Carver, D. J.: The immediate psychological effects of tobacco smoking. Journal of Comparative Psychology, 1922, ii, 279–302.

[3] Johnson, B.: Practice effects in a target test: A comparative study of groups varying in intelligence. Psychological Review, 1919, xxvi, 302–303.

A master target (see fig. 8) was made on tracing cloth and from this a number of blue-print targets were reproduced. When the targets began to show depreciation from continued pricking, they were easily replaced by gluing a new target over the old one. The target consisted of a blue field with white rings and white cross lines. There was a central white disc of 1¼ inches in diameter. The succeeding discs had radii of 3, 6, 9, 12, and 15 inches[4] respectively with ⅛-inch rings of demarcation. The target bore both a vertical and a horizontal cross line, white, ⅛-inch in width, each extending from edge to edge of the target sheet, and intersecting at the center of the bull's eye. These divided the target into four quadrants, enabling the examiner to estimate whether the reactor was undershooting or overshooting the mark, as well as to ascertain to what extent he was banking his hits to the right or to the left of the vertical dividing line. These lines at the same time destroyed the illusion of a tunnel which resulted from unbroken concentric rings and which was a source of annoyance to the reactor.

The target was supported vertically, with the center of the bull's eye 61 inches from the floor, and with its vertical plane 15 feet from the reactor's "toe line." Illumination was secured from a 60 candle power nitrogen filled mazda lamp placed obliquely at a suitable distance from the target, with a metal reflector which shielded the reactor's eyes from the direct light.

The daily and hourly schedules of reactors are shown in tables 1 and 2. The hour for conducting tests was accommodated to the study program of the several reactors, they being undergraduate students in the University. In so far as was possible, each reactor worked on the same hour on each of his days.

In order to obviate stage fright, self consciousness and other personal disturbances, a practice period of seven days was allowed to reactors working under schedules 1 and 2. On these practice days the reactor refrained from smoking in the part of the day preceding the giving of the test. Alternation of smoking and non-smoking at this time might have well been undertaken in order to study the learning abilities when smoking and when not smoking. Failure to do so, however, had no bearing upon the test as it was presented and evaluated.

---

[4] In Carver's article, page 294, the diameter of ring 2 is given as 29 inches, which is a clerical error, 24 inches being the actual measurement.

TABLE 1

Distribution of working days of the individual reactors

The numbers indicate the schedules of the different days

DATE	REACTORS					
	1	2	3	4	5	6
October 6	1					1
October 7	1		1		1	1
October 8	1	1	1		1	
October 9	1		1			1
October 11		1		4	1	1
October 12		1		4	1	1
October 13	1		1	4	1	1
October 14	1	1	1		1	1
October 15	1	1	1		1	
October 16	1		1			1
October 18		1		4	1	2
October 19		1		4	2	1
October 20	2		1	4	1	2
October 21	1	1	2		2	1
October 22		2	1		1	
October 23	2		2			
October 23		1		5	2	
October 26		2		4	1	2
October 27	1		1	5	2	1
October 28	2	1	2		1	
October 29	1	2	1		2	
October 30			2			
November 1		1		4	1	2
November 3	2		1	5	2	1
November 4	1	2	2		1	2
November 5	2	1	1		2	
November 6	1		2			1
November 9		2				
November 10	2		1		1	2
November 11		1	2			
November 12	1	2	1		2	
November 13	2		2			
November 15		1		4	1	
November 16		2		5	2	1
November 17	1		1	4	1	2
November 18	2	1	2		2	1
November 19	1	2	1			
November	2		2			2
November 22		1		5		1
November 23		2		4		2
November 29		1		5		
November 30		2		4		1
December 1	1			5		2
December 2	2					

In conducting the test after the smoking was introduced, non-smoking days and smoking days were allowed to alternate until ten days of each had been concluded, making in all twenty-seven days for each reactor.

After reaching the laboratory, the reactor remained seated from fifteen to twenty minutes preceding the throwing of darts. On the non-smoking days this constituted a rest period, and on smoking days it provided the interval in which reactor smoked. In this manner the time of the throwing was kept at a near constant—thirty to thirty-five minutes. Upon the word "set up" the reactor took a position "toeing" a line 15 feet from target, and grasped in the left hand 13 darts, taking them from a table placed at his left, and waited for the word "go." At "go" he began throwing the darts at the target with the rate and force which seemed to him most suitable. As soon as he had thrown the 13 darts, he took 12 more from the same table, and continued throwing until these were gone. By this method the reactor's attention was distracted but once from the bull's eye. All darts remained where they stuck in the target until the set of 25 had been finished and scored.

TABLE 2

Working hours of the reactors

Fifty minutes, beginning at the hours indicated

Reactor 1	Wednesday, Thursday, Friday, Saturday, 9:30
Reactor 2	Monday, Tuesday, 9:30; Thursday, Friday, 10:30
Reactor 3	Wednesday, Thursday, Friday, 8:30; Saturday, 10:30
Reactor 4	Monday, Tuesday, Wednesday, 10:30
Reactor 5	Monday, Tuesday, Wednesday, Thursday, Friday, 2:00
Reactor 6	Monday, Tuesday, Wednesday, Thursday, Saturday, 3:00

The first day of throwing, the reactor was told to confine himself to overhand throws, and to hold the dart in such manner as seemed to him to conduce to accurate throwing. In every instance the reactor chose to grasp the dart between the first two fingers and thumb, close to the metal socket of the point. This method of throwing was continued throughout the tests.

The experimenter scored the darts as they were thrown by noting the circle in which the hits fell, the bull's eye being scored

6 and the succeeding circles scored as 5, 4, 3, 2, and 1. All hits without the outer circle were scored 0. When the experimenter was in any doubt concerning the accuracy of the scoring, a recount was made at the end of the set. The darts were then withdrawn by the experimenter, who, as he withdrew them, scored the hits in the four quadrants.

Two minutes of rest (reactor seated), were allowed between each of the daily 12 sets of throws of 25 to the set. This method was used instead of a "headway" of a certain number of minutes, as employed by Carver, in order to have a definite time for scoring a set and collecting the darts for the next set. However, as the test worked out, the "headway" was fairly constant at from two and one half to three minutes. There was but a difference of a few seconds between the average throwing time of the different reactors, with the exception of reactor 4.

Six reactors were employed in the test, 5 of them for twenty-seven days each on schedules 1 and 2, the other (reactor 4), for nineteen days on schedules 4 and 5.

From the outlines of the individual's "observable characteristics," it may be said that the 6 reactors were apparently mentally normal young men. With continued observation of the reactors and their performances, certain traits which might be considered by some theorists as "neurotic" became evident. Such traits would be found in every intelligent individual under continued observation.

The tests occurred in a quiet room, no one being present except the reactor and the experimenter. Daily records were kept of the temperature and humidity in the room, and records of barometric pressure were obtained from the Baltimore station of the Weather Bureau. A study of these records revealed nothing which could account for variations in the performance, and hence the records are not here inserted.

2. The regulation of smoking in connection with the tests

Under schedule 1 the reactor refrained from smoking in the portion of the day preceding the giving of the test, and did not smoke for the test.

Under schedule 2 the reactor refrained from smoking each day preceding the giving of the test, but smoked one cigar or two cigarettes in the fifteen or twenty minutes immediately preceding the throwing of darts, other conditions remaining the same as under schedule 1. Cigars and cigarettes were not alternatives, but each reactor confined himself to the one or the other.

Under schedule 4, the reactor, (a habitual smoker) did not refrain from smoking but continued his use of tobacco as usual. He smoked before coming to the laboratory but not thereafter.

Under schedule 5, the reactor desisted from smoking on the day of the test and did not smoke for the test.

In every case from beginning to end of reactor's daily performance, the duration was approximately fifty minutes.

Schedules 1 and 5 may at times in this inquiry be referred to as non-smoking test days, and schedules 2 and 4 referred to as smoking test days. In the case of reactors 1, 2, 3, 5, and 6, schedule 1 was followed for the first seven (practice) days, and thereafter schedules 1 and 2 were followed on alternate days. For reactor 4, schedule 4 was substituted for schedule 1, and 5 for 2.

The cigars used were of a commercially well known brand, made in Baltimore, of claro-colorado strength, retailing at 10 cents. They were of practically the same grade as the cigars used by Carver, but were not the same brand, the size and strength desired being temporarily unobtainable in the former brand. The cigarettes were of a popular brand, running very uniform in strength.

The amount of tobacco smoked by each reactor in each smoking day was estimated by the procedure described below. Although, as Carver has pointed out, such attempted standardization has little significance, it was thought well to keep the record. It must be distinctly understood, however, that we do not assume that the quantity of smoke products absorbed by the reactors varies simply with the quantity of tobacco burned. Nor do we assume that the weights give exactly the actual amount of tobacco, since in spite of our attempts to keep the cigars uniformly moist in the humidor, the moisture undoubtedly varied.

Fifty cigars of the type and kind used for tests were stripped of their trade-mark bands and weighed. The weighing took place immediately upon the breaking of seals and removal from the box. The average weight of a cigar was found to be 5.9267 grams. The fifty cigars were next placed one at a time upon the balance, and the one weighing nearest to the average weight was selected. The first (pointed) inch of this cigar was cut off and weighed, its weight being 1.11 grams. The next inch, more or less constant in its cylindrical form, was then cut off and weighed. This was found to weigh 1.405 grams. The weight per $\frac{1}{8}$ inch of the cylindrical part was then: $\frac{1.405}{8} = 0.1756$ gram.

When conducting the tests the portion of each cigar unsmoked at the conclusion of the interval for smoking was measured to the eighth of an inch, and the weight of the tobacco smoked thus estimated. The deviations due to the slightly different weights of individual cigars are too small to be considered.

Sixty cigarettes were in like manner weighed and the average computed to be 1.1408 grams per cigarette. The cigarette being of a uniform cylindrical shape, the smoked portion was determined in a manner simpler than that for the cigar. No deduction was made for the paper wrapper.

The approximate weights of tobacco smoked by each reactor on each of his smoking days are given in table 3.

3. *Personal notes on the six reactors*

The reactors were undergraduate students in the University, and were representative types, so far as intelligence, scholarship and general health are concerned. The experimenter not only controlled the work of these men during the dart-throwing periods as carefully as possible, making the daily routine uniform, but also obtained daily information on the state of health, sleep and general activities of each man, and kept watch of their behavior throughout the experiment, for indications of emotional peculiarities and changes. Each man was interrogated as to his own beliefs and attitudes concerning the use of tobacco, in order that any possible effect of bias upon the man's endeavor might be noted. The net result of the observations and interrogations which are reported below was to convince the experimenter that the 6 reactors were "normal," and were coöperating fully with the experimenter.

TABLE 3

Smoking schedules of reactors, indicating grams of tobacco consumed for each day's test

DATE	REACTOR 1 (CIGARETTES)	REACTOR 2 (CIGARETTES)	REACTOR 3 (CIGARS)	REACTOR 5 (CIGARS)	REACTOR 6 (CIGARS)
October 18					4.46
October 19				4.81	
October 20	1.65				3.41
October 21			3.06	4.11	
October 22		1.65			
October 23	1.65		4.11		
October 25				3.58	
October 26		1.71			2.00
October 27				3.76	
October 28	1.40		3.93		
October 29		1.65		4.11	
October 30			3.58		
November 1					3.41
November 3	1.45			4.64	
November 4		1.55	3.93		3.58
November 5	1.60			4.11	
November 6			4.46		
November 9		1.65			
November 10	1.71				4.11
November 11			4.46		
November 12		1.71		5.16	
November 13	1.55		3.58		
November 16		1.65		4.81	
November 17					3.58
November 18	1.71		4.11	4.81	
November 19		1.65			
November 20	1.65		4.11		4.11
November 23		1.65			4.46
November 30		1.65			
December 1					3.76
December 2	1.50				

It must be distinctly understood that while the statements as to the reactors smoking habits are, in substance, the reactors' own reports on the matter, the summaries of the reactors' temperamental, emotional, and motor characteristics are the experimenter's opinions, based on daily observations and on information informally elicited from the reactors during the preliminary 'resting' or smoking period. While the summaries indicate divers temperamental tendencies, they are all such as may be expected concerning normally healthy young men.

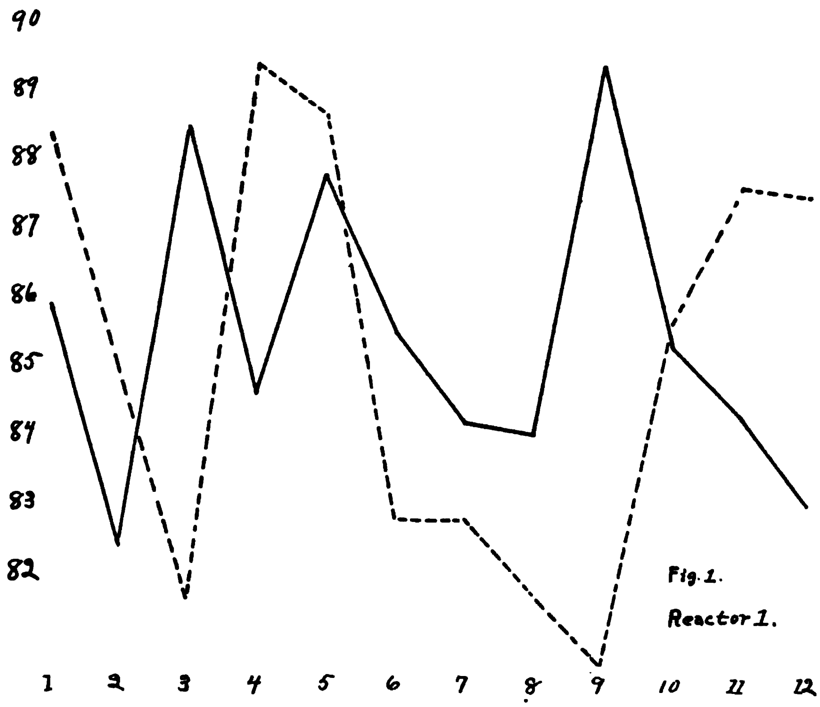


FIG. 1

Reactor 1. Age nineteen years, ten months.

This reactor smoked his first cigarette about three years ago. He then smoked at intervals for a short while and discontinued the use of tobacco for about a year and a half. At present he smokes only when with his associates, and then for mere sociability. He states that he does not enjoy smoking, and feels that it is injurious to his health. He is an expert swimmer and refrains from the use of tobacco when making trials or entering contests, as he is of the impression that his breath is shortened from its use. He states that he has formed no habit, as he has no difficulty in discontinuing smoking whenever he desires. Reactor does not inhale the smoke.

Reactor 1 developed a tendency to ennui as the tests progressed. At times he seemed capricious in his throwing, changing his rate and his speed without apparent reason. This was noted on a number of occasions, but on October 29 and November 4 and 5 particularly. He maintained throughout the tests a recurring disposition to experiment with his own throwing. On October 16, after a good set of throws, he announced, "I am going to make a record." The next hit fell in an outer circle after which he began to throw in a somewhat haphazard manner. At the conclusion of the test he volunteered that when he "went wild on the first throw" it was difficult to continue his throws thereafter with accuracy. The reason he gave was "he just got discouraged." No other emotional or temperamental reasons were evidenced that might affect his precision in throwing than have already been noted.

Reactor 2. Age twenty-one years, ten months.

This reactor smoked for the first time at nine years of age. He has not been an habitual smoker. When in military training at Plattsburg in the summer of 1918, he smoked from five to six cigarettes a day. In the Student Officers Training Corps, in the fall of 1918, he continued smoking but at this time began using a pipe. On one occasion he was made sick from its use. After this he discontinued smoking altogether and has not used tobacco since, excepting for the tests as are here described. He has never tried to inhale tobacco smoke.

Reactor 2 seems to entertain no prejudice as to smoking in general. He admits that he personally enjoys it. He does not approve of drastic legislation in regard to smoking, but favors such legislation as the West Virginia smoking laws, where, under the law, no person under sixteen years of age is allowed to smoke and no one under twenty-one years is permitted to smoke a cigarette.

In the dart-throwing tests, reactor 2 at first appeared to be ill at ease or easily embarrassed, but for the greater part of the experiment he was quite at ease. Trivial things at times seemed to distract his attention from his throwing, much to the detriment of his aim. On October 15 the reactor in several throws at the beginning of the test threw wide of the mark. Thereafter he seemed to lose control of the darts. It seemed to be an accident if he approached the center of the target.

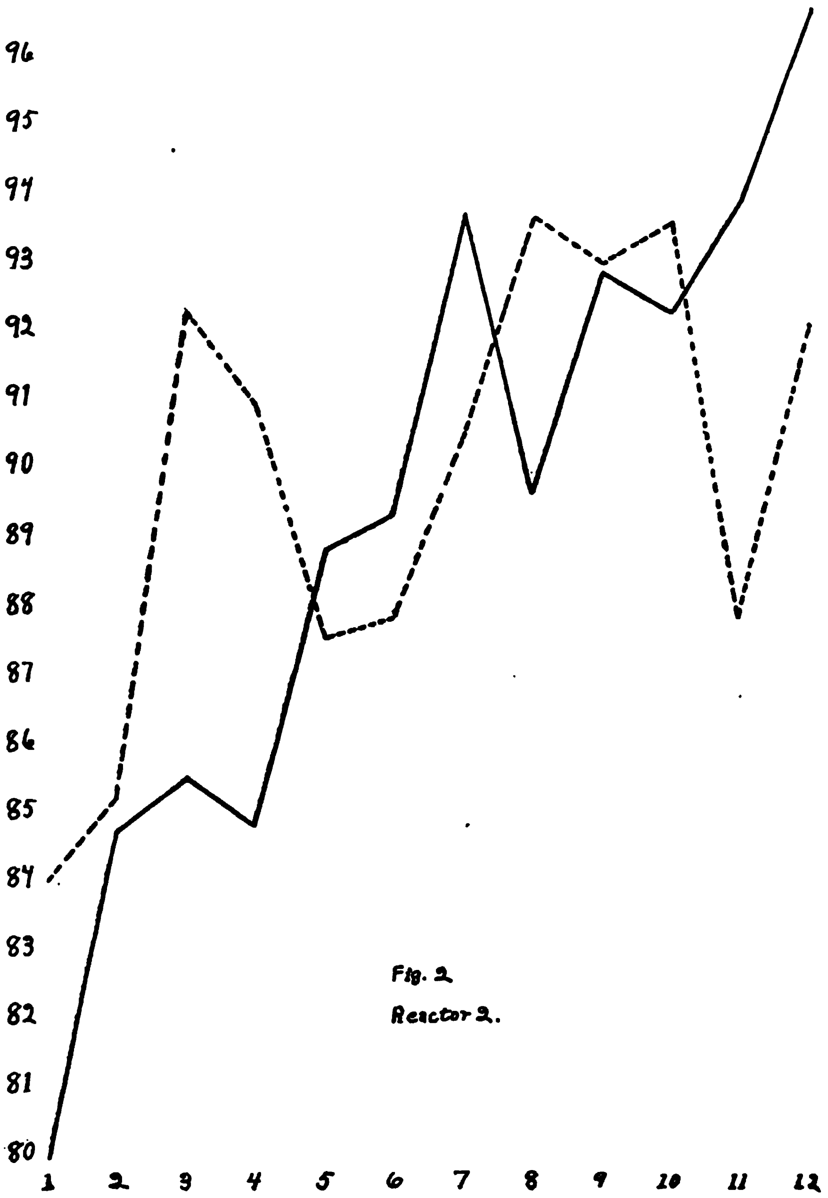

96
95
94
93
92
91
90
89
88
87
86
85
84
83
82
81
80
1
2
3
4
5
6
7
8
9
10
11
12
Fig. 2
Reactor 2.

FIG. 2

Some of the darts stuck in the floor as close as 10 feet from the reactor. The hits seemed to be confined to no one quadrant, but the tendency seemed to be to the lower left. While the test was in progress, the reactor laughed hysterically at his inability to control his aim. He ventured the statement at the time, "When I make a wild throw I cannot get my eye off of that dart." Before the end of the period he had regained his former control. This incident is related in detail as the same condition manifested itself on October 19, 22 and 26, and for other intervals of but short duration.

Reactor at times seemed to be affected by a depression which he characterized as "the blues," and which at times would give way to high spirits or exuberance. October 18, reactor stated that he was feeling dejected. This he attributed to the weather, it being rather close and oppressive and somewhat foggy. The thermometer stood at 76°. On October 19 reactor still indicated a feeling of dejection and at the conclusion of the test, when a cause for this was requested, replied that "everything looked so hopeless" to him. Upon questioning him at the close of the tests, the reactor stated that is he more at ease with one individual than he is with a crowd. In a crowd he states that "he is lost." He bites his lips when under stress or strain in order to compose himself. He states that he forces himself into situations and in recent months has discovered that he reacts with considerably more self-composure. He is susceptible to worrying at slight provocation, has a vivid imagination—"too vivid"—and at times has feelings of irritability. He is exceedingly sensitive, his particular dread seems to be that some one may impeach his honesty or impute to him improper motives in conduct. He used to have feelings that he was being depreciated or disparaged by his associates but at present feels that he is overcoming this condition. He formerly preferred to be alone but has forced himself into situations until he feels that he has become more sociably inclined.

Reactor 3. Age eighteen years, eight months.

Reactor 3 smoked for the first time at nine or ten years of age. He began with corn silk and the like and gradually took up tobacco. Since July last he has been an habitual and regular smoker. Prior to that time he indulged occasionally, in his own words, "when he felt bad and bold," and then he used cigars or pipe. As a rule he has never been a cigarette smoker. He alleges his chief reason for indulgence is "to occupy his time." He states he never uses tobacco during school hours but smokes a pipe before and after the day's classes, and smokes a pipe while he studies of an evening. This reactor can inhale tobacco smoke into his lungs.

This reactor seemed to entertain no feeling against either smoker or non-smoker. He stated that he would desire to have his or others' privileges respecting the use of tobacco neither restricted nor relaxed by legislation.

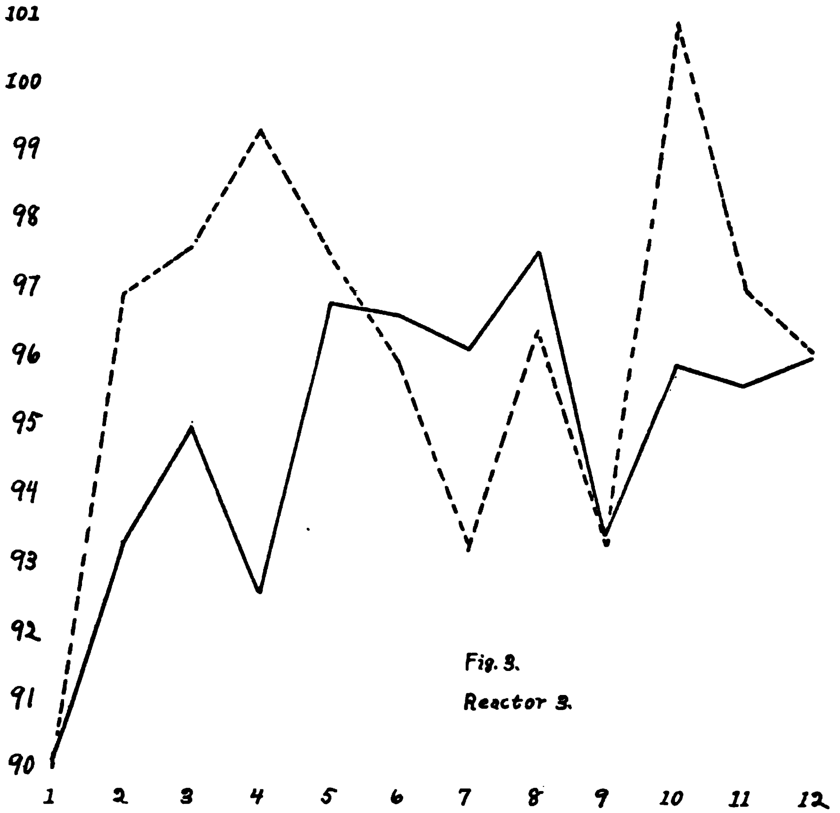


FIG. 3

Reactor 3 manifested throughout the tests a fidgety, restless disposition and was inclined to be somewhat garrulous. His restlessness took the form of repeatedly shifting his position in his seat while the darts were being counted for the succeeding test. He was usually alert and responsive at the command to begin throwing. He frequently hugged his knees as he sat. While he maintained this tendency throughout the giving of the tests, the trait was particularly noticed on October 20 and 30. He has a light-hearted and genial disposition and possibly attaches much weight to his own conduct and utterances. During his early practice days he was inclined to put a kind of physical contortion into his throws—a "winding up", in baseball parlance. He leaves the impression of possessing a type of abandon which gives a spontaneity to his actions and his utterances. On several occasions he whistled a tune as he threw (seventh set of October 22, and third and fourth sets of October 23). He usually anticipated the words "set up," and even the word "go." This was first noted October 20 and the trait persisted throughout the entire performance of the tests. He kept a mental account of his hits—even to the point of a keen competition with himself. October 29 and November 10 were noted as possible exceptions. He strove to exceed his former records and expressed chagrin upon his failure to obtain his desired success, this particularly when his first throw or throws went wide of the bull's eye. He stated on one occasion October 29, that he was nervous but could give no adequate definition of what he meant by the term, excepting mental and physical restlessness. In his words, he "cannot stick to one thing for a long time," and, as he further states, has a lack of ability to accomplish a thing through tedious effort. For the period of the tests a feeling of well-being or exuberance seemed to be his characteristic mood.

He has had some five operations performed upon his throat and nose for the removal and treatment of tonsils and adenoids. These operations were performed between his fourth and fifteenth years of age.

Reactor 4. Reactor 4 began smoking at the age of thirteen. He took up tobacco by way of corn silk, fine wood shavings and the like. He smokes at present from six to ten cigarettes daily. He never smokes cigars and seldom smokes a pipe. Cigars give him a headache and too many cigarettes produce a feeling of oppression about his head. He smokes, as he alleges, because he "enjoys it." He has discontinued his habit for as much as two months at a time, the last about a year ago. He states that he never thinks of smoking so long as his attention is distracted from it or where he knows it is impossible to smoke.

This reactor insists that adults may smoke, but that the use of tobacco should be denied to those who have not reached physical maturity, and designates eighteen as the approximate age of maturity.

Throughout the tests the reactor maintained a slow, deliberate rhythm in throwing his darts. This was possibly due to throwing over the wrong foot (right). He never learned to throw in any other manner. The duration of time for throwing sets of 25 was materially lessened towards the end of the tests. The reactor has a quiet, unassuming manner and is inclined to neatness in his general physical appearance. He states he is of a nervous temperament. In childhood he alleges he was easily made to cry, the cause being that others regarded his endeavors with indifference. The taking of an activity out of his hands, or displacing him in any way, caused a resentment on his part. At the present time these feelings persist. His feelings of greatest dejection are produced by some one "throwing cold water" on his activities. In viewing motion pictures he formerly was unable to witness the exciting parts, and repeatedly found himself closing his eyes until a happier progress was presented. The reactor admits that he is given to "building air castles" and to daydreaming. He encounters difficulties when he is required to act out of concert with others and complains of a stage fright in which his flow of speech is impeded. He states he has a persistent dream of a "barrel" that grows in size and

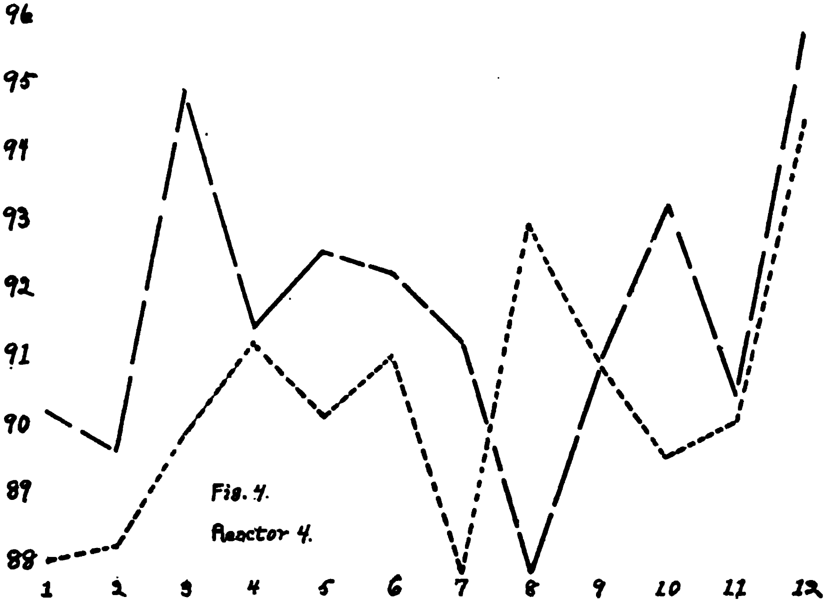


FIG. 4

from which he escapes with difficulty as it rolls along. At times in his sleep he has a feeling that his legs are tied and when he calls for help is unable to utter a sound. These conditions might seem to indicate a state of self-consciousness in conjunction with a sense of inadequacy or inferiority. The reactor alleges that he felt composed throughout the dart-throwing tests.

Reactor 5. Age eighteen years, six months.

This reactor smoked for the first time in December, 1919, being at a club meeting when cigars were passed around. After that he averaged about one cigar a month. The past summer he smoked about one cigar a week. Home influences were against the use of tobacco. Since October he has been continually increasing his amount of smoking. At the present time he sometimes smokes several cigarettes a day. Formerly he smoked for sociability; at the present time it is a source of enjoyment. He inhales somewhat. He sees no reason why adults

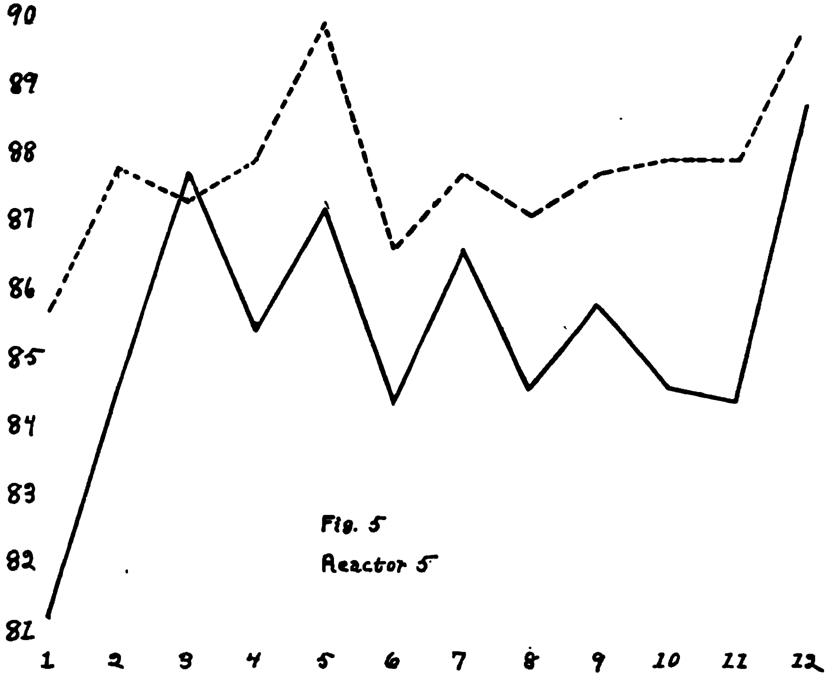


FIG. 5

should not smoke if they desire to. He states that the best grades he has made in his studies have been since he has become a regular smoker.

The reactor maintained throughout the tests his disposition to throw the darts in as rapid succession as was possible with consistent aiming. He attained the point where he could make 25 throws, with interval for grasping the latter 12 included, in thirty-three seconds. He kept his impulsive force, according to close observation, at nearly a constant. Combining a nearly constant rapidity of throwing with a nearly constant force injected a factor into the throwing that makes his results of considerable significance when compared with the results of others. Reactor is alert and quick of both perception and reaction. This seems to be borne out in his rapidity of speech and in the quickness of his stride. He is the possessor of a prize scholarship and does well in his classes.

He gave a history of a paroxysmal contraction, of two years ago, of the muscles of his back, and stated that he was of the impression that his (few) wide throws to the lower-left were due to a muscular contraction of his arm. He stated that his knee reflexes were unequal, but upon examination the examiner could find no inequality. Reactor did have a very fine muscular tremor of his fingers.

The reactor stated that he observed a difference in the grasp of his darts at the conclusion of the test from that of the beginning. The same observation was also made by reactors 1 and 3, the difference they represented being that of firmness or tenacity of hold. This aspect of throwing possibly results from a reduction of activity to a near automatism on the part of the reactor as the test progresses through the daily test interval.

Reactor 6. Age eighteen years, four months.

Reactor 6 smoked for the first time at the age of twelve. The cigar he used at that time made him sick. He has used tobacco regularly for the past three years. He smokes cigarettes mostly and a pipe to some extent, and inhales the smoke of both into his lungs. A package of cigarettes—20 cigarettes—lasts him about three days. The reactor evidently has smoking "sprees." On one occasion last spring, he alleges, he smoked three packages of cigarettes, one cigarette after another. His motive in smoking, in his own words, is " to keep him company."

The reactor is averse to having any smoking privilege restricted, but is of the opinion that the use of tobacco might well be prohibited during the period of physical immaturity.

Reactor 6 threw with varying rates of speed and of force throughout the entire tests. Without apparent reason he would throw with great force and follow the same throw with one of much less intensity. This characteristic, no doubt, has the effect of reducing the import and value of the test findings. The lack of constancy, together with his varying deliberateness, seemed to be temperamental. He states that under stress or excitement he has an emotional muscular trembling. He detailed a recent incident where, in selling tickets at a football game, he felt his rights had been infringed upon by another so employed, and a verbal altercation ensued. After the matter had been adjusted he experienced this muscular trembling for some moments. On October 26 he demanded a reason for biting his finger nails, stating that he had gone to the extent of putting aloes upon his fingers to overcome this habit, but continues it undiminished. On examination they were discovered to be bitten down close to the flesh. Though the flesh had not been penetrated, it had been somewhat roughened thereby. He finds it unpleasant to turn around quickly for even a small number of times and finds it impossible to ride on a "merry-go-round" on account of the dizziness and nausea that ensues. While engaging in high-school

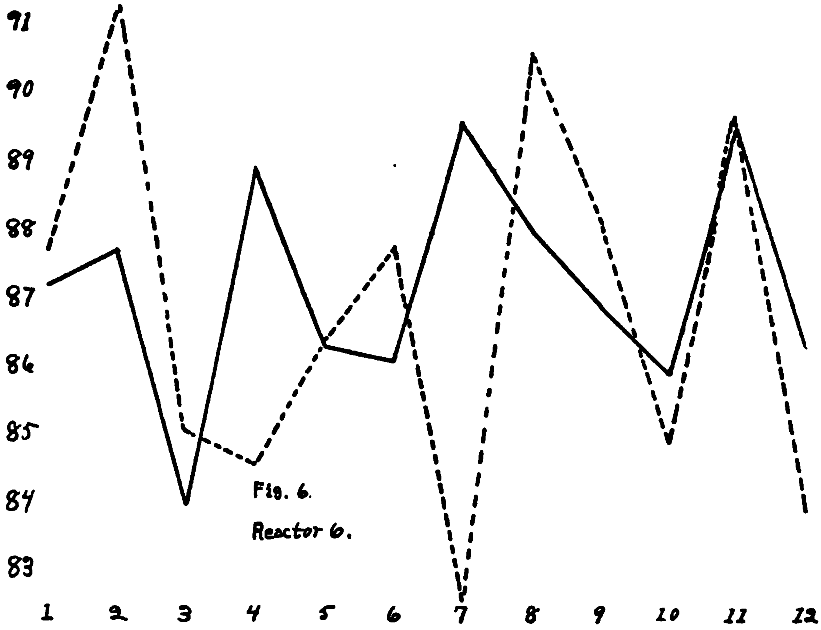


FIG. 6

athletics he was, on one occasion, struck on the head by a vaulting bar and received a severe skull injury. From this he fancies he still feels ill effects when very warm. He had a tendency in the laboratory to step as though he were afraid he would disturb some one, and reacted in the examiner's presence as though he were cultivating an air of composure.

A résumé of the general conditions of health, sleep and exercise for each working day of each reactor is given in tables 4 to 9.

The hours of going to bed and the duration of sleep for the preceding night are, of course, estimations, for the reliability of which we depended on the reactor's report. But since these reports were obtained each working day, for the preceding night, it may be reasonably assumed that they are approximations to the facts. These data are presented in order that any reader who may question whether certain variations were not due to physiological or other general conditions of the individual may satisfy himself on that point. The author's conclusion is that the variations cannot be so simply explained. In the first line of tables 4 to 9, D indicates preceding day, N indicates preceding night, and M indicates morning of the same day.

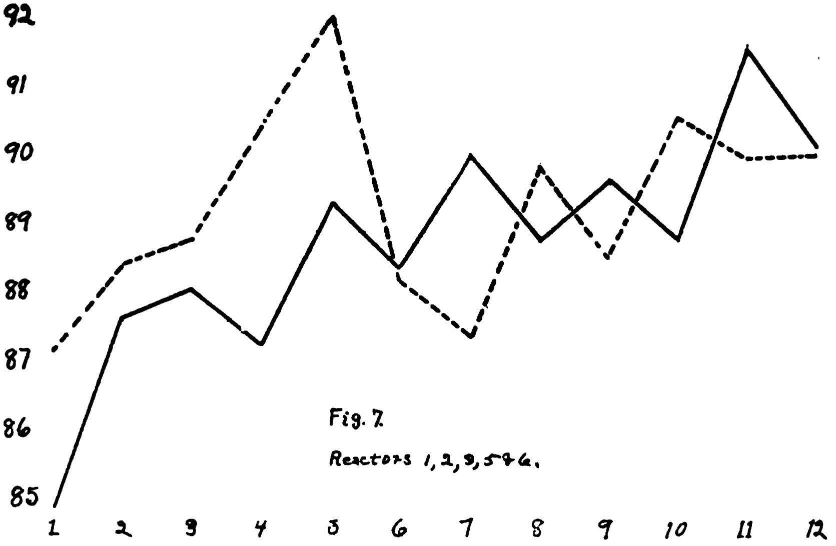


FIG. 7

TABLE 4

Résumé of psychobiological conditions

Reactor 1

	OCTOBER										NOVEMBER										DECEMBER	
	13	14	15	16	20	21	23	27	28	29	3	4	5	6	10	12	13	17	18	19	1	2
Smoked last	Smoked for test only																					
Cigar																						
Cigarette																						
Pipe																						
Went to bed	12	12	12	1	11	11	1	12	2	12	2	12	12	12	12	11	1	11	11	1	12	1
Hours of sleep	7	8½	7½	8	8	8	6	7	7	7	5½	8	7	8	7¼	8½	7	8½	8	7½	8½	8
Slept well	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Slept badly																						x
Today's exercise:																						
Walked 7 blocks	x	x	x	x	x	x		x	x	x	x	x		x	x	x	x	x	x	x	x	x
Tennis one-half hour							x															
Ran 3 blocks													x									
Hour before test:																						
Walked 7 blocks	x	x	x	x	x	x		x	x	x	x	x			x	x	x	x	x		x	x
Tennis one-half hour							x															
In class														x						x		
Reading at university													x									

Estimate of bodily feelings:																						
As usual	x	x	x	x	x	x		x	x		x	x	x	x	x	x	x	x	x	x	x	x
Better than usual							x			x												
Indisposed																						
Alert as usual	x	x	x	x	x	x		x	x		x	x	x	x	x	x		x	x	x	x	x
Less alert																	x					
More alert							x			x												
Present worries:																						
Family matters																	x					x
Money matters								x														
Health																						
Studies																						
Social relations	Generally satisfactory																					

TABLE 5

Résumé of psychobiological conditions

Reactor 2

	OCTOBER								NOVEMBER														DECEMBER
	15	18	19	22	25	26	28	29	1	4	5	9	11	12	15	16	18	19	22	23	29	30	2
Smoked last	Smoked for tests only																						
Cigar																							
Cigarette																							
Pipe																							
Went to bed	12	11	11	11	12	11	1	1	1	11	12	12	12	12	12	12	12	12	12	12	12	12	12
Hours of sleep	7	7½	7	8	7½	8	6½	6	6½	7½	7	7	7½	7½	7	7½	7	7	7½	7	7	7½	7
Slept well	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Slept badly			x																				
Today's exercises:																							
Walked to laboratory									x	x	x	x	x	x			x	x	x	x	x	x	x
Nothing in especial	x	x	x	x	x	x	x	x							x	x							
Hour before test:																							
In class	x			x			x	x		x	x		x	x			x	x					x
Reading in library		x	x		x	x			x			x				x			x	x	x	x	
Came from home (in car)															x								
Estimate of bodily feelings:																							
As usual	x	x				x	x	x		x		x	x		x	x	x	x	x	x	x	x	
Better than usual				x	x						x			x									x

Indisposed			x						x														
Alert as usual	x					x	x	x		x		x				x	x	x	x	x			
Less alert		x	x						x				x		x						x	x	
More alert				x	x						x			x									x
Calm			x	x	x	x	x	x	x	x	x	x	x	x						x	x		
Restless	x	x													x	x	x	x	x			x	x
Present worries:																							
Family matters																						x	
Money matters																							
Health									x														
Studies												x											
Social relations	Satisfactory, excepting with girl friends																						

TABLE 6

Résumé of psychobiological conditions

Reactor 3

	OCTOBER											NOVEMBER											
	13	15	16	20	21	22	23	27	28	29	30	3	4	5	6	10	11	12	13	17	18	19	20
Last smoked	D	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Cigar																							
Cigarette	x							x					x	x									x
Pipe		x	x	x	x	x	x		x	x	x	x			x	x	x	x	x	x	x	x	
Went to bed	11	12	12	12	12	11	1	12	12	11	12	3	11	11	12	10	12	12	12	12	12	12	11
Hours of sleep	8	7	9	7	7½	8	9	7½	7	8	9	4	8	8	8½	9	7½	7	8	8	8	10½	8
Slept well	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Slept badly																							
Today's exercise:																							
Ran up steps	x		x	x	x	x	x		x	x													
Walked to school								x				x	x	x	x	x	x	x	x	x	x	x	x
Hour before test:																							
Eating breakfast	x	x	x	x	x			x		x		x	x		x	x	x	x		x	x	x	x
Chemical laboratory																			x				
No report						x	x		x		x			x									
Estimate of bodily feelings:																							
As usual	x		x	x	x		x	x	x			x	x	x	x	x	x	x	x	x	x	x	x
Better than usual		x				x				x	x												

Hour before test.
Eating breakfast
Chemical laboratory
No report

Indisposed																							
Alert as usual		x	x	x			x	x			x		x	x		x		x	x	x	x	x	x
Less alert												x											
More alert	x				x	x			x	x					x		x						
Calm	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Restless																							
Present worries:																							
Family matters																							
Money matters																							
Health																							
Studies																							
Social relationships	Generally satisfactory																						

TABLE 6

Résumé of psychobiological conditions

Reactor 3

	OCTOBER											NOVEMBER											
	13	15	16	20	21	22	23	27	28	29	30	3	4	5	6	10	11	12	13	17	18	19	20
Last smoked	D	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Cigar																							
Cigarette	x							x					x	x									x
Pipe		x	x	x	x	x	x		x	x	x	x			x	x	x	x	x	x	x	x	
Went to bed	11	12	12	12	12	11	1	12	12	11	12	3	11	11	12	10	12	12	12	12	12	12	11
Hours of sleep	8	7	9	7	7½	8	9	7½	7	8	9	4	8	8	8½	9	7½	7	8	8	8	10½	8
Slept well	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Slept badly																							
Today's exercise:																							
Ran up steps	x		x	x	x	x	x		x	x													
Walked to school								x				x	x	x	x	x	x	x	x	x	x	x	x
Hour before test:																							
Eating breakfast	x	x	x	x	x			x		x		x	x		x	x	x	x		x	x	x	x
Chemical laboratory																			x				
No report						x	x		x		x			x									
Estimate of bodily feelings:																							
As usual	x		x	x	x		x	x	x			x	x	x	x	x	x	x	x	x	x	x	x
Better than usual		x				x				x	x												

Indisposed																							
Alert as usual		x	x	x			x	x			x		x	x		x		x	x	x	x	x	x
Less alert												x											
More alert	x				x	x			x	x					x		x						
Calm	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Restless																							
Present worries:																							
Family matters																							
Money matters																							
Health																							
Studies																							
Social relationships	Generally satisfactory																						

TABLE 7

Résumé of psychobiological conditions

Reactor 4

	OCTOBER								NOVEMBER									DECEMBER			
	12	13	18	19	20	25	26	27	1	8	15	16	17	22	23	29	30	1	6	7	8
Smoked last	M	M	M	M	M	D	M	D	M	N	M	D	M	N	M	D	M	N	M	N	M
Cigar																					
Cigarette	2	2	2	x	2		2		2		2		4		2		3		3		4
Pipe																					
Went to bed	10	11	8	9	12	8	11	11	9	11	10	10	11	9	11	10	11	11	10	11	12
Hours of sleep	9	8	10½	10	7	9	8	7½	10	8	9	8	7½	10	7½	9	8	8	9	8	7
Slept well		x	x		x	x	x	x	x	x	x	x	x	x	x		x	x		x	x
Slept badly	x			x												x			x		
Today's exercise:																					
To school on car	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Hour before test:																					
In class	x		x	x		x	x		x		x	x		x	x	x	x		x	x	
Studying in library		x			x			x		x			x					x			x
Estimate of bodily feelings:																					
As usual	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x
Better than usual																					
Indisposed																			x*		
Alert as usual	x	x		x	x	x	x		x	x	x		x	x	x	x	x	x		x	x
Less alert			x									x							x		

More alert								x													
Calm	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x
Restless													x								
Present worries:																					
Family matters																					
Money matters																					
Health																					
Studies	x														x						x
Social relationships	Generally satisfactory																				

---

* Feels dejected.

TABLE 8

Résumé of psychobiological conditions

Reactor 5

	OCTOBER													NOVEMBER									
	13	14	15	18	19	20	21	22	25	26	27	28	29	1	3	4	5	10	12	15	16	17	18
Smoked last						D		D	D	D		D				D	M		M	D	D	D	M
Cigar						x		x	x	x		x				x				x		x	
Cigarette																	x		x		x		x
Pipe																							
Went to bed	10	11	10	9.30	10	11	12	11	11	12	11	11	11	11	10	12	11	12	11	11	11	12	11
Hours of sleep	8½	8	8	10	9	7½	6½	8½	8	7	7½	7	8	8	8	6½	8½	6	7½	8½	7½	6	7½
Slept well	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x
Slept badly										x													
Today's exercise:																							
Walked 1½ miles	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x
Nothing in especial										x													
Hour before test:																							
Walked 8 blocks			x	x			x	x			x	x	x	x		x	x						
Ate lunch									x	x													
In class or laboratory	x	x				x																	
Reading in library					x									x	x	x			x	x		x	x
Playing cards				x				x	x														
Estimate of bodily feelings																							
As usual	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x					
Better than usual																							

Indisposed								x*											x*	x*	x*	x*	x*
Alert as usual	x	x		x	x	x		x		x	x	x	x	x	x	x	x	x	x		x	x	
Less alert			x				x		x											x			x
More alert																							
Calm	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Restless																							
Present worries:																							
Family matters																							
Money matters																x		x	x	x	x	x	x
Health																							
Studies			x										x	x									
Social relationships	Satisfactory, excepting with girl friends, October 14 to November 1																						

---

* October 22, headache. November 12, 15, 16, 17, 18, nasal cold.

TABLE 9

Résumé of psychobiological conditions

Reactor 6

	OCTOBER										NOVEMBER												DECEMBER
	12	13	14	16	18	19	20	21	26	27	1	3	4	6	10	16	17	18	20	22	28	30	1
Smoked last	D	D	N	D	D	N	N	N		D	D	M	D	D	D	D			N			N	
Cigar										½													
Cigarette	4	4	5	6	5						3	x	3		x	x			2				
Pipe					4	x	x	x						x								x	
Went to bed	11	11	12	10	11	11	11	12	11	11	11	12	10	11	11	11	11	11	11	11	1	11	11
Hours of sleep	8	8½	7¼	8	7¾	7¾	7½	7	8	8	8	7	8	8	8	8	8	7½	8	8	6	8	8
Slept well	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Slept badly																							
Today's exercise:																							
Walked 20 blocks	x	x	x	x	x	x	x	x						x	x				x	x			
Nothing in especial									x	x	x	x	x			x	x	x			x	x	x
Hour before test:																							
Came from home	x							x	x					x									
In class or laboratory		x			x	x	x			x		x			x		x						
Reading in library			x								x		x			x		x		x	x	x	x
Surveying				x															x				

Estimate of bodily feelings:																							
As usual	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Better than usual																							
Indisposed		x*																					
Alert as usual				x	x	x	x	x	x	x		x	x	x	x			x					
Less alert	x	x	x								x					x	x		x	x	x	x	x
More alert																							
Calm	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Restless																							
Present worries:																							
Family matters																							
Money matters																							
Health																							
Studies	x									x							x	x		x			x
Social relationships	Generally satisfactory																						

---

* Slight headache.

TABLE 10

Target scores, consecutive sets

Reactor 1

DATE	1	2	3	4	5	6	7	8	9	10	11	12	AVERAGE
Schedule 1 (practice)													
October 6	78	84	86	75	73	81	83	79	76	82	75	80	79.33
October 7	82	100	86	82	88	86	80	80	80	88	89	89	85.00
October 8	82	94	88	91	93	97	98	96	86	99	89	81	91.16
October 9	74	75	90	95	75	76	97	93	90	103	100	89	88.08
October 13	86	84	84	104	76	92	92	91	90	83	88	108	89.75
October 14	83	73	86	90	94	88	90	87	76	87	89	74	84.75
October 15	81	76	74	82	69	91	90	83	72	94	106	98	84.66
Average	80.9	83.7	84.6	88.4	81.1	87.4	90.0	87.0	81.4	90.9	90.9	88.4	
Schedule 2													
October 20	92	106	107	104	97	101	97	89	92	84	75		94.90
October 23	102	83	72	82	79	92	77	83	99	100	85		86.72
October 28	78	66	84	56	92	80	69	77	74	84			76.00
November 3	84	88	93	87	99	84	88	94	103	76	91	78	88.75
November 5	82	63	95	94	83	89	89	100	100	87	104	103	90.75
November 10	81	98	98	94	91	93	95	88	75	76	63	99	87.58
November 13	90	95	103	81	84	77	63	78	80	83	61	66	80.08
November 18	78	77	80	73	101	96	92	80	79	80	91	62	82.41
November 20	87	79	70	86	82	81	91	78	91	79	94	91	84.08
December 2	86	70	80	90	71	63	82	74	102	105	96		83.54
Average	86.0	82.5	88.2	84.7	87.9	85.6	84.3	84.1	89.5	85.4	84.4	83.1	*85.50*

Schedule 1

October 16	94	87	93	100	82	88	87	66	86	87	88		87.09
October 21	86	87	89	92	85	84	71	78	77	90	67	88	82.83
October 27	104	95	74	81	89	104	81	79	69	76	91	71	84.50
October 29	105	79	83	96	94	80	78	79	72	65	100	91	85.16
November 4	83	73	90	93	83	90	96	83	85	84	66	87	84.41
November 6	80	82	70	67	88	85	95	92	99	106	109	87	88.33
November 12	81	76	90	85	85	75	89	86	87	88	85	85	84.33
November 17	95	86	80	89	88	70	76	81	65	78	96	91	81.25
November 19	89	74	83	101	101	71	81	93	89	90	94	106	89.33
December 1	68	70	65	91	93	82	75	81	79	93	81	83	80.08
Average	88.5	80.9	81.7	89.5	88.8	82.9	82.9	81.8	80.8	85.7	87.7	87.6	84.9

TABLE 11

Target scores, consecutive sets

Reactor 2

DATE	1	2	3	4	5	6	7	8	9	10	11	12	AVERAGE
Schedule 1 (practice)													
October 8	90	103	98	92	99	94	95	90	92	83	101	92	94.08
October 11	81	83	89	71	83	70	78	91	91	100	88	86	84.25
October 12	80	83	77	63	60	62	94	71	83	79	74	67	74.41
October 14	77	80	85	86	75	84	93	75	97	67	76	91	82:17
October 15	84	79	91	70	68	58	48	41	41	46	79	79	65.33
October 18	81	93	101	91	93	99	83	90	83	88	86	84	89.33
October 19	92	77	68	79	92	69	76	76	75	77	84	78	78.58
Average	83.6	85.4	87.0	78.9	81.4	76.6	81.0	76.3	80.3	77.1	84.0	82.4	
Schedule 2													
October 22	71	74	86	72	82	78	93	78	74	88			79.60
October 26	77	68	68	51	72	74	64	82	78	93	88	90	75.42
October 29	88	85	89	93	88	96	109	96	101	96	99	101	95.08
November 4	70	83	77	75	84	87	95	82	91	88	89	89	84.17
November 9	80	90	91	95	93	97	96	95	100	81	93	102	92.75
November 12	73	94	88	97	94	94	92	89	99	91	96	92	91.58
November 16	84	89	92	100	96	95	104	96	95	92	100	98	95.08
November 19	84	87	89	91	103	92	97	89	96	99	102	106	94.58
November 23	87	81	81	84	87	85	96	91	99	98	96	103	90.92
November 30	86	94	95	91	90	96	91	99	96	97	96	106	94.75
Average	80.0	84.8	85.6	84.9	88.9	89.4	93.7	89.7	92.9	92.3	93.9	96.7	89.4

Schedule 1

October 21	85	82	86	82	59	59	83	72	83	85			77.60
October 25	83	62	94	86	71	67	65	78	83	87	76	83	77.92
October 28	89	96	95	102	96	91	96	107	91	96	94	92	95.42
November 1	87	86	90	93	88	84	92	88	99	85	85	90	88.92
November 5	72	93	93	97	87	88	95	100	98	95	90	96	92.00
November 11	84	90	96	90	94	98	94	106	100	96	95	96	94.92
November 15	88	89	101	91	101	102	97	96	106	97	101	89	96.50
November 18	90	84	86	82	85	91	93	98	90	95	94	99	90.58
November 22	72	82	92	89	99	99	98	92	91	98	71	106	90.75
November 29	91	89	91	98	96	100	92	100	89	102	95	92	94.58
Average	84.1	85.3	92.4	91.0	87.6	87.9	90.5	93.7	93.0	93.6	87.9	92.1	*89.9*

TABLE 12

Target scores, consecutive sets

Reactor 3

DATE	1	2	3	4	5	6	7	8	9	10	11	12	AVERAGE
Schedule 1 (practice)													
October 7	80	72	94	91	90	90	78	84	95	90	92	84	86.66
October 8	84	95	93	98	97	96	85	87	93	90			91.80
October 9	74	78	89	90	102	86	91	83	89	77	88		86.09
October 13	81	97	86	91	89	93	89	88	77	84	105	94	89.51
October 15	85	97	91	88	93	89	77	88	66	92	100	97	88.58
October 16	70	85	91	92	73	82	86	85	102	102	97	81	87.16
Average	79.0	87.3	90.6	91.6	90.6	89.3	84.3	85.8	87.0	87.5	96.4	89.0	
Schedule 1													
October 20	93	97	95	103	101	91	88	104	89	101	98	97	96.41
October 22	79	101	94	101	101	79	99	87	90	97	84	78	90.83
October 27	99	100	106	95	102	103	88	94	88	100	104		98.09
October 29	89	99	94	96	102	93	80	84	93	99	97	98	93.66
November 3	88	96	102	94	101	104	104	107	95	96	103	103	99.41
November 5	96	101	100	104	94	98	94	104	99	91	91	98	97.50
November 10	86	95	95	100	84	97	94	96	88	109	94	96	94.50
November 12	86	91	99	105	100	101	90	96	92	109	91	102	96.66
November 17	94	90	105	104	92	98	97	100	102	96	112	105	99.50
November 19	91	100	87	92	99	105	99	93	98	112	97	89	99.83
Average	90.1	97.0	97.7	99.4	97.6	96.9	93.3	96.5	93.4	101.0	97.1	96.2	*96.37*

Schedule 2

October 21	77	86	94	83	84	81	96	98	96	91	94		89.09
October 23	89	75	96	94	100	97	96	98	95	98	99	103	95.00
October 28	80	105	96	99	103	99	98	97	80	86	96		94.45
October 30	93	92	93	93	105	97	99	108	99	99	100	103	98.41
November 4	91	97	93	100	88	98	93	93	91	105	93	98	95.00
November 6	100	99	100	103	104	95	100	98	95	99	90	91	97.83
November 11	90	101	90	97	100	104	96	92	97	88	100		95.91
November 13	96	93	94	88	102	99	91	96	97	98	100	96	95.83
November 18	89	93	98	85	96	96	104	108	96	98	89	98	95.83
November 20	97	93	97	85	87	101	89	89	89	98	96	84	92.08
Average	90.2	93.4	95.1	92.7	96.9	96.7	96.2	97.7	93.5	96.0	95.7	96.1	94.92

TABLE 13

Target scores, consecutive sets

Reactor 4

DATE	1	2	3	4	5	6	7	8	9	10	11	12	AVERAGE
Schedule 4 (practice)													
October 11	72	93	83	79	87	89	87	89	87	89			85.50
October 12	43	74	91	82	87	90	80	84	94	80	81	89	81.25
October 13	73	88	84	87	91	91	88	80	84	82	90	87	83.41
October 18	68	74	87	67	73	75	70	79	74	84			75.10
October 19	84	89	90	83	75	83	79	85	84	86	82	80	83.33
Average	68.0	83.6	87.0	79.6	82.6	85.6	80.8	83.4	84.6	84.2	84.3	85.3	
Schedule 5													
October 25	94	97	86	92	100	99	87	73	77	82	92		89.00
October 27	73	76	93	93	85	86	77	99	92	80	83	90	85.58
November 3	93	87	86	87	79	90	88	99	96	97	90	88	90.00
November 16	85	93	88	85	87	80	87	96	91	87	82		87.36
November 22	95	88	82	95	83	88	90	106	86	89	79	100	90.08
November 29	83	90	102	92	95	88	76	87	100	96	87	85	90.08
December 1	91	82	88	87	99	97	102	95	96	95	105	108	95.41
December 8	91	93	95	99	94	101	96	89	90	91	103	96	94.83
Average	88.1	88.3	90.0	91.3	90.2	91.1	87.9	93.0	91.0	89.6	90.1	94.5	*90.26*

Schedule 4

October 20	90	98	88	82	94	98	96	95	94	94	93	101	93.58
October 26	83	99	92	98	102	94	104	80	100	94	91	104	95.08
November 1	88	79	96	93	89	90	89	92	91	96	98		91.00
November 15	87	86	91	87	87	96	85	81	92	87	75	96	87.50
November 17	91	82	98	99	96	91	85	82	92	101	86	88	90.91
November 23	85	94	95	87	89	87	96	93	92	91	96	91	91.33
November 30	93	92	107	91	89	83	86	97	83	83	90	101	91.25
December 6	105	87	93	94	95	99	89	83	84	100	95	90	92.83
Average	90.3	89.6	95.0	91.5	92.6	92.3	91.3	87.9	91.0	93.3	90.5	95.8	*91.70*

TABLE 14

Target scores, consecutive sets

Reactor 5

DATE	1	2	3	4	5	6	7	8	9	10	11	12	AVERAGE
Schedule 1 (practice)													
October 7	65	96	88	92	83	90	94	85	86	105	83	90	87.66
October 8	83	86	85	96	91	88	89	91	91	80	84	86	87.50
October 11	84	88	77	76	89	95	77	81	87	77	87	91	84.08
October 12	85	79	80	98	93	74	83	80	72	97	85	80	83.88
October 13	86	101	84	89	87	88	85	81	76	84	93	90	84.00
October 14	86	81	91	86	83	92	87	91	82	90	77	86	86.00
October 15	82	94	90	91	84	78	82	89	87	95	96	77	87.06
Average	81.6	89.3	85.0	89.7	87.1	86.4	85.3	85.4	83.0	89.7	86.4	85.7	
Schedule 2													
October 19	74	64	88	91	91	79	89	79	69	67	71	83	78.75
October 21	64	77	77	73	95	82	82	70	80	74	78	91	78.58
October 25	86	99	91	72	79	78	82	87	78	87	79	79	83.08
October 27	76	96	85	88	87	86	87	84	85	84	88	90	86.33
October 29	85	80	89	88	89	87	97	84	90	92	91	92	88.66
November 3	84	84	87	83	84	92	87	83	100	92	95	95	88.85
November 5	89	90	97	92	84	79	84	92	86	86	84	90	87.75
November 12	89	87	90	96	85	86	97	86	86	91	94	86	89.41
November 16	84	81	81	86	85	84	77	86	95	92	83	92	85.50
November 18	82	89	93	86	94	92	85	96	90	82	82	90	88.44
Average	81.3	84.7	87.8	85.5	87.3	84.5	86.7	84.7	85.9	84.7	84.5	88.8	*85.53*

Schedule 1

October 18	72	78	88	104	88	84	89	84	86	79	91	83	85.50
October 20	70	90	84	87	95	85	85	78	80	89	91	85	84.91
October 22	88	94	86	77	86	94	82	97	86	83	86	91	87.50
October 26	81	82	81	83	89	68	87	80	83	80	79	87	81.66
October 28	88	88	82	81	93	87	93	82	86	89	84	92	87.08
November 1	92	88	88	88	91	87	87	90	88	93	90	94	89.66
November 4	82	88	86	94	92	89	84	87	93	97	93	91	89.66
November 10	99	86	88	95	78	93	96	100	87	97	81	101	91.75
November 15	105	92	100	92	99	86	85	91	101	86	88	94	92.41
November 17	81	93	91	79	89	94	90	83	88	87	97	89	88.44
Average	85.8	87.9	87.4	88.0	90.0	86.7	87.8	87.2	87.8	88.0	88.0	90.7	87.94

TABLE 15

Target scores, consecutive sets

Reactor 6

DATE	1	2	3	4	5	6	7	8	9	10	11	12	AVERAGE
Schedule 1 (practice)													
October 6	77	90	67	89	82	82	67	93	81	74	86	82	80.83
October 7	75	88	89	95	92	89	89	86	84	92	76	94	87.41
October 9	71	95	84	86	90	76	86	89	81	94	88	97	86.41
October 11	84	84	85	85	70	83	94	97	86	77	95	94	86.17
October 12	79	71	76	91	88	84	82	76	83	88	82	87	82.25
October 13	77	87	74	90	95	95	87	99	87	85	80	73	85.75
October 14	88	80	89	85	83	83	86	75	88	78	87	77	83.25
Average	78.7	85.0	80.6	88.7	85.7	84.6	84.7	87.9	84.3	84.0	84.9	86.3	
Schedule 2													
October 18	79	96	90	97	86	83	94	82	72	91	93	77	86.66
October 20	80	91	83	84	84	88	83	85	83	92	97	93	86.92
October 26	93	74	73	90	84	80	89	78	68	73	87	81	80.82
November 1	102	100	76	90	75	81	87	86	94	84	84	88	87.25
November 4	81	83	82	79	78	89	83	89	92	90	84	90	85.00
November 10	77	85	88	80	82	89	103	93	90	78	85	89	86.58
November 17	87	80	84	88	89	92	82	88	87	82	78	68	83.75
November 20	89	88	85	86	97	77	87	90	88	84	103	82	88.00
November 23	89	85	90	95	97	93	98	87	98	94	90	97	92.75
December 1	96	96	90	101	92	90	91	103	98	92	96	99	95.33
Average	87.3	87.8	84.1	89.0	86.4	86.2	89.7	88.1	87.0	86.0	89.6	86.4	*87.30*

Schedule 1

October 16	90	93	81	73	91	87	87	87	79	72	83	68	82.58
October 19	84	83	96	90	81	86	78	84	83	87	93	82	85.42
October 21	95	81	88	76	93	89	80	96	92	82	98	88	88.17
October 27	74	89	82	94	91	94	74	87	90	85	86	84	85.83
November 3	82	96	82	92	92	91	95	92	94	82	105	83	90.50
November 6	99	98	84	87	88	87	78	95	94	95	88	96	90.75
November 16	92	90	87	97	78	88	82	98	81	80	85	83	86.83
November 18	79	89	72	71	81	84	76	96	83	87	79	76	79.42
November 22	90	97	82	84	80	85	77	76	94	85	82	94	85.50
November 30	93	98	98	83	90	88	100	96	92	95	98	86	93.08
Average	87.8	91.4	85.2	84.7	86.5	87.9	82.7	90.7	88.2	85.0	89.7	84.0	*86.98*

4. *Daily and average scores*

Tables 10 to 15 give the scores for each set of each reactor in the practice series and in the twenty-days' series of the two test schedules. Averages are given for each day's work at the end of the lines for the days; averages for all of the first sets, second sets, etc., for the ten days of each schedule, at the bottoms of the columns; and the general average for each of the schedules is given in italics. The average deviation (mean variation) and probable error of these general averages are given in table 16. The graphs in figures 1 to 7 are drawn from the set-averages of these tables. The scores for each set were obtained, as described above, by counting each dart in the bull's eye (circle 6) as 6 points, and darts in the other rings from the center as 5, 4, 3, 2 and 1, respectively. Darts falling outside the limits of the largest circle (circle 1) were counted as zero.

TABLE 16

Mean variations and probable errors of the average scores

	REACTOR					
	1	2	3	4	5	6
Smoking						
Mean variation	9.27	7.66	4.74	9.74	5.45	5.86
Probable error	7.84	6.48	3.77	8.17	4.59	4.95
Non-smoking						
Mean variation	7.74	7.98	5.51	5.97	4.90	6.06
Probable error	6.60	6.74	4.66	5.05	4.14	5.12

The average scores for the "smoking" days and the "non-smoking" days of reactors 1, 2, 3, 5 and 6 show little difference. Reactors 1 and 2, who were non-smokers during the months of the tests, except for the prescribed smoking of schedule 2, have scores 0.6 per cent better in the smoking and 0.5 per cent better in the non-smoking schedules, respectively. This is a remarkably close approximation of the two scores in each case. Of the 3 smokers, reactors 3 and 5 have non-smoking scores 1.45 per cent and 2.41 per cent better than their smoking scores, but reactor

6 has a smoking score 0.32 per cent better than his non-smoking score. The difference for this reactor is so small that it is entirely negligible. It will be noted from the "personal notes" (p. 377) that reactors 1 and 2, who smoked cigarettes in the test, did not inhale the smoke. This is, of course, important in connection with the negative results for their tests. But reactor, 6 who shows negative results, did inhale.

The results so far then, indicate that the *immediate* effects of moderate smoking (1 cigar or 2 cigarettes) vary from negligibility to slight disturbance of accuracy by the smoking: results quite in accordance with Carver's findings.

Reactor 4, who worked on a different schedule, has a higher average score (1.48 per cent) on his smoking days than on his non-smoking days. But in this case there is no immediate effect of smoking, since the reactor did not smoke in any of the tests; but rather an effect of abstinence, during the preceding part of the day, from his accustomed smoking. If we could assume that reactors 3 and 5, on the non-smoking days, were deleteriously affected by abstinence from the customary smoking during the non-smoking days, and that on the smoking days, the effects of the smoking during the tests were mixed, the deteriorative (for these reactors) immediate effects being complicated by the partial removal of the effects of abstinence, the score-difference for these reactors would become of more importance. But in any case, the difference in the scores of these two reactors seems to indicate a slight detrimental immediate effect of smoking, for although the differences are less than 2 per cent, and less than the probable error, they are based on a sufficiently large number of cases (approximately 3000 darts in each of the two schedules).

5. *The actual distribution of darts*

The method of scoring by any definite values to the several rings of the target, is, of course, arbitrary, and it might be suspected that other methods of scoring might give different results. For this reason, the comparisons are made in table 17 on the basis of the actual percentages of the total number of darts in the total smoking and non-smoking sets (3000 darts in each, in most cases) included within the several rings and the bull's eye.

It will be noted that in table 17 the percentages for each circle include the percentages for the circles within that circle. For example: the percentage for circle 4 includes darts in circles 5 and 6, as those darts are all within 4.

TABLE 17

Percentages of darts within the several rings of the target

REACTOR	SCHEDULE	RINGS					
		6	5	4	3	2	1
1	1	0.8	19.7	52.8	78.4	91.4	96.3
	2	0.9	20.1	53.7	79.2	91.1	96.7
2	1	0.5	22.0	59.8	84.2	94.9	98.2
	2	1.3	22.2	59.8	83.4	93.4	97.2
3	1	1.4	27.2	68.0	90.8	98.1	99.6
	2	1.3	24.3	66.7	90.1	97.6	99.5
4	4	1.0	22.3	62.2	86.4	95.7	98.8
	5	1.3	22.3	59.1	84.3	95.1	98.5
5	1	1.0	20.5	56.6	81.1	94.0	97.4
	2	1.0	18.8	53.2	79.0	92.2	97.3
6	1	1.2	20.1	55.4	80.1	93.2	97.7
	2	0.9	19.6	56.0	81.6	93.1	97.9

In table 17 it is seen that reactor 1 shows but slight difference between the number of darts within any ring for smoking and non-smoking schedules. No simple method of scoring would make the total scores for the two schedules differ to an important extent. Reactor 2 shows slightly more difference between the two schedules; a slightly higher number for the bull's eye (ring 6), the same number within ring 4, and fewer in rings 3, 2, and 1; in the smoking as compared with the non-smoking schedule. In other words, a tendency to scatter, in this smoking schedule, in a certain way, so that a few more of the highly successful (bull's eye) throws, and a few more "wild" throws, are made, than in the non-smoking schedules. Nevertheless, the total tendency to scatter is less in the smoking schedule for this reactor than in the non-smoking, as shown by the measures of variation (table 16). The distribution curve for the two schedules is of a different type. It is interesting to note that of the total throws of all reactors which completely missed the target, 240 were on "smoking" days, 208 on "non-smoking."

Reactors 3 and 5, while showing approximately the same percentages of hits in the bull's eye, in both schedules, show a higher percentage in the second, third, fourth and fifth rings in the smoking schedule than in the non-smoking: a showing entirely in accord with the results of the scores in tables 10 and 14. Reactor 6, whose "smoking" score in table 15 is very slightly better (0.32 per cent) than his non-smoking score, has a slightly higher number of darts in the bull's eye and in ring 5 in the non-smoking schedule, but has a higher number within rings 4 and 3 in the smoking. In other words, the scatter is less for the smoking score.

Reactor 4, who worked on schedules different from those of the other reactors, with a somewhat better score on the "smoked as usual" days (schedule 4) than on the abstinence days, shows distributions consistent with the difference, for although more bull's eyes were made on abstinence days, more darts were placed within the fourth, third and second rings and as many within the fifth and first on the smoking days, the darts averaging nearer the center on the smoking days.

The method of scoring, therefore, appears to be adequate, and the measure of variation also may be taken from the scores. The average deviation of the total scores for each reactor are given in table 16, together with the probable errors of the scores. In every case but one, the variation is less for the smoking days: in the case of reactor 2, the variation is slightly higher for the smoking days. In other words, the distribution is more uniform —less scattering—after smoking. This effect of tobacco is apparently independent of the effect on the average score.

6. *Variations in efficiency throughout the hour*

The progress of the throwing through the working hour shows some interesting peculiarities. On all except a few days, 12 sets of 25 darts each were thrown in schedules 1 and 2. The scores for each set on each day are given in tables 10 to 15, and the set-averages (that is, the averages for the first set on the ten days of each schedule, the average of the second set on the ten days, and so on) are given at the bottom of the column for each schedule. These set-averages show significant variations.

The graphs of figures 1 to 6 show the values of the set-averages for each reactor. In each figure, the numbers at the left are score values, and the numbers at the bottom indicate the successive sets of 25 darts each thrown in each hour. The dotted line in figures 1, 2, 3, 5 and 6 represents the course of the set averages for the non-smoking days; the solid line in these figures represents the course for the smoking days. Each of the 12 ordinates of each graph represents, therefore, the average of the scores of the corresponding set on ten days: representing, therefore, a total of 250 darts each.

In figure 4, the dotted line represents the "deprivation of smoking" schedule (schedule 5), and the broken line the "smoking as usual" schedule (schedule 4).

In general, the fluctuation of the smoking averages are less violent than those of the non-smoking. In other words, the smoking averages show a more consistent course from the first to the twelfth. This is especially noticeable in reactors 1, 2, 3 and 6, not significantly with 4 and 5. It is noticeable that in every case there is a slump in the non-smoking curve towards the middle of the hour, with recovery towards the end. The smoking curve of reactors 4 and 5 show similar slumps and recoveries, but the smoking curve of reactors 2 and 6 show no such slump, and the slump for reactors 1 and 3 occurs at the end of the smoking curves. It is interesting to note that each of these pairs of reactors consists of a cigarette smoker and a cigar smoker, and also that there is here a distinct effect of the smoking on reactors 1 and 2, although the average daily scores of these reactors are not affected significantly, as shown in tables 10 and 11.

The general tendencies discoverable in the graphs of the several subjects are clearly apparent in the graph of the combined average of reactors 1, 2, 3, 5 and 6 (fig. 7). This graph shows a higher average score for schedule 1 (non-smoking) over schedule 2 for the early part of the hours: then a slump followed by recovery. The greater consistency of the "smoking" work is clearly apparent. While the group averages of the reactors' scores would not by itself be admissible evidence, it is significant in connection with the individual scores and does actually exhibit a general tendency, in spite of the individual variations.

Apparently, we have here a distinct effect of smoking. The course of efficiency throughout the hour is the same for all reactors, when they have not recently smoked: there is in all cases a tendency to slump after the first spurt, and a subsequent recovery. But immediately after smoking, the course of the efficiency is different for 4 reactors. One reactor fails to show this difference, and the remaining reactor (reactor 4) was not tested immediately after smoking. The fact that the alteration in the course of the efficiency for 2 reactors is somewhat different from that for the other 2 may reasonably be considered a matter of individual difference in susceptibility, or difference in the temporal course of the tobacco effects. It is possible that the 2 reactors who show no terminal slump in the smoking curve would have shown it a little later: that is to say, that the effects of smoking in all 4 cases is to *postpone* the slump. The one reactor (reactor 5) who shows no disturbance of the course of efficiency by smoking, is one who shows no other significant effect of smoking.

7. *Vertical and horizontal distributions*

As has been described above, the target was divided, by vertical and horizontal lines through the center of the bull's eye, into four quadrants. Records were kept of the number of darts in each set falling in each quadrant, and analyses were made of these records in order to find possible significant variations in the vertical and lateral distributions of the darts. These analyses yielded nothing of consequence. Table 18 presents the general averages of the smoking and non-smoking sets of each reactor, showing the average number of darts falling in upper and lower halves of the target, and in the right and left halves. It will be noticed that the vertical distribution for each reactor is approximately the same for each of his two schedules, and that although there is perhaps a tendency on the part on Reactors 1, 3, 5 and 6 to throw more to the left after smoking, as compared with the non-smoking schedule, the evidence for this tendency is unimportant. The analysis of the quadrants in respect to daily differences and differences in the progressive sets of the hour was likewise productive of negative results. It was noted, however, that there are characteristic individual differences in distribution, some reactors having a distribution wider vertically than horizontally, others the reverse, and others showing a diagonal distribution. It was also noted that there were two tendencies shown after making wild throws, some reactors tending to throw the next dart into the opposite quadrant, as in over compensating for the error, others not showing this tendency. This factor as a detail in the correction of error might well be studied during the early learning period, in respect to its effect on improvement.

TABLE 18

Average vertical and horizontal distribution of darts

REACTOR	SCHEDULE	UPPER	LOWER	RIGHT	LEFT
1	1	11.00	14.00	12.36	12.64
	2	10.47	14.53	12.20	12.80
2	1	11.76	13.24	11.52	13.48
	2	11.51	13.49	11.90	13.10
3	1	12.18	12.82	13.92	11.08
	2	12.12	12.88	13.74	11.26
4	4	10.81	14.19	13.70	11.30
	5	10.08	14.92	13.17	11.83
5	1	11.40	13.60	11.80	13.20
	2	12.19	12.81	11.00	14.00
6	1	13.07	11.93	12.43	12.57
	2	12.55	12.45	12.05	12.95

8. Speed of throwing

The time taken by the subject in throwing each set of 25 darts was taken with a stop-watch throughout the whole series of tests. The average throwing times for the 6 reactors are given in table 19, in which it will be noticed that the time is slightly shorter for the smoking schedule (schedule 2) of reactors 2, 5, and 6, and slightly longer for reactors 1 and 2, than for the non-smoking schedule. The difference seems negligible, especially in view of the values of the coefficient of correlation between speed and accuracy, *r*, in the same table.

TABLE 19

Average time of throwing a set (25) of darts, and coefficients of correlation between speed and accuracy of throwing

	REACTORS					
	1	2	3	4	5	6
	Non-smoking					
Average deviation	44.85	41.42	48.18	60.40	35.30	51.36
r	0.58	−0.38	−0.22	−0.24	−0.30	−0.006
	Smoking					
Average deviation	45.25	41.29	47.37	61.97	34.70	50.02
r	−0.12	−0.61	−0.33	−0.11	−0.17	0.04

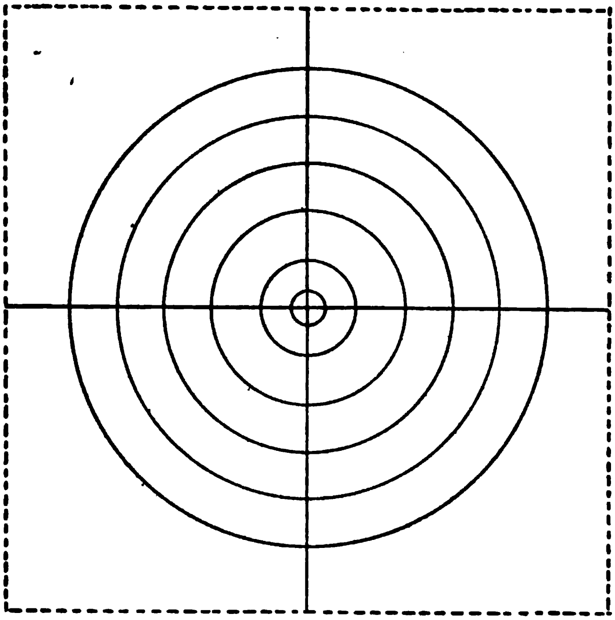


FIG. 8. PATTERN FOR TARGET ONE-TWELFTH ACTUAL DIAMETER

The targets were blue-printed from this pattern and hence had white bull's eye, rings and cross-lines, on a dark blue ground. The dotted lines indicate the edges of the target.

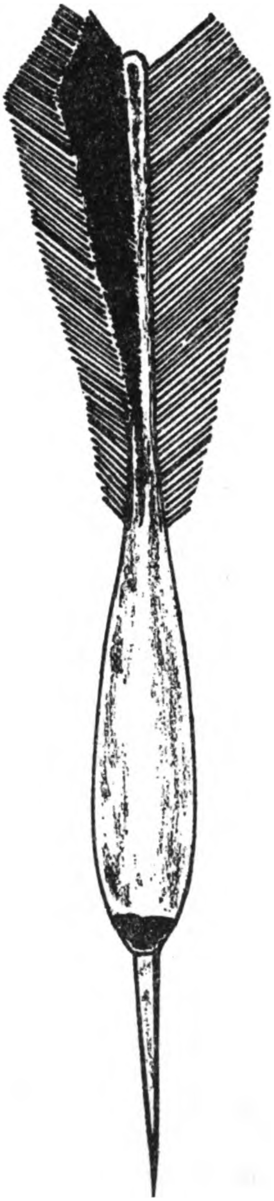


FIG. 9. DART ACTUAL SIZE

The body and tail are wood, the point of steel; the tail is feathered. Length of dart (including point, body and tail, exclusive of feathers) 6 inches. Weight approximately 12.8 grams.

THE INSTINCTIVE LOCOMOTOR REACTIONS OF THE LOGGERHEAD TURTLE IN RELATION TO ITS SENSES

G. H. PARKER

Zoölogical Laboratory, Harvard University

The young loggerhead turtle, Caretta caretta Linn., on hatching is immediately active and commonly takes a rather direct course from its sandy nest to the sea by means that I have elsewhere discussed (Parker, 1922). Its locomotion under these circumstances is of the type seen in most terrestrial vertebrates in that the diagonal legs act together lifting the animal and throwing it forward.

When such newly hatched turtles are put into an aquarium of seawater, their reactions are as characteristic in this new environment as they were in the old one. The turtles immediately assume a new set of responses which are for the most part strikingly stereotyped and novel. They commonly rest by floating on the surface of the water and under these conditions the head is held symmetrically forward, the anterior flippers are folded over the upper edge of the carapace, and the posterior ones are held in a vertical position near the sides of the body. The turtle gives the general appearance of having been snugly folded up (fig. 1).

Surface swimming is usually accomplished by a paddling movement of the appendages which is like ordinary crawling in that the diagonal legs strike at the same time and the two sets of appendages alternate in action. This form of swimming is commonly abandoned as soon as the turtle goes below the surface. Here it usually moves by a kind of submarine flight well known to all visitors of those aquaria in which sea-turtles are kept. This type of locomotion is accomplished almost exclusively by the anterior flippers which are moved as a pair up and down over the back of the animal much as the wings of a bird are. In vigorous movements of this kind the right and left flippers touch each other at the end of their excursions over the back and are then brought down with a vigorous stroke on each side of the animal. This flight movement is accomplished almost entirely by the anterior appendages, the posterior ones being carried passively along or used at most as rudders. This type of locomotion is the most rapid of which the turtle is capable and is commonly employed in escape. If a young turtle is caught between the thumb and forefinger of the experimenter and held horizontally in the air, it almost always begins rapid flight movements with its front flippers.

In surface paddling and in submarine flight the young turtles almost always maintain a balanced position with the back up and ventral side down. If by accident they are thrown laterally so that one side is lower than the other, they quickly recover by unsymmetrical movements of the anterior flippers. When a young turtle is held between the fingers of the experimenter and in a horizontal position the flight movements of the anterior flippers are commonly carried out, but, if during these movements, the turtle is turned with one side down, righting movements appear with almost machine-like regularity. These righting movements are accomplished chiefly by the anterior flippers the lower of which makes vigorous cross-wise strokes while the upper one is held almost motionless and directed over the back (fig. 2). By the action chiefly of the momentarily lower flipper the turtle is brought quickly into a horizontal position dorsal side up. If the turtle is held with the left side down, the left front flipper is the one chiefly concerned with righting. If, while this operation is going on, the turtle is quickly turned so that the right side is down, in an instant the whole scheme of movement reverses symmetrically and the right front flipper assumes the chief rôle, the left being held motionless. When a turtle is quickly turned first with one side down and then with the other, the corresponding reversals in the activity of the front flippers occur with such regularity and quickness as to give one the impression of machine-like response. If the turtle is held ventral side up, righting reactions, such as have already been described, are quickly assumed, but they are of double character in that for a brief time the righting strokes are made by the front flipper of one side and then by that of the other side. Thus an alternation of activity goes on first on one side then on the other. The fact that all these locomotor responses, including righting, are carried out with great regularity and completeness by young turtles immediately on hatching shows at once that they are unquestionably instinctive in character.

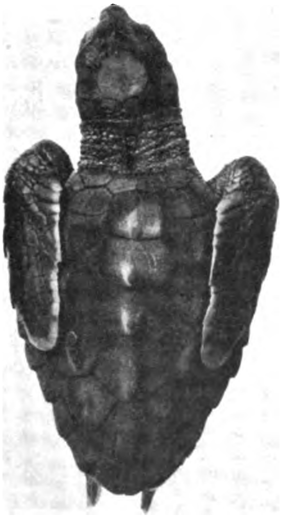


Fig. 1

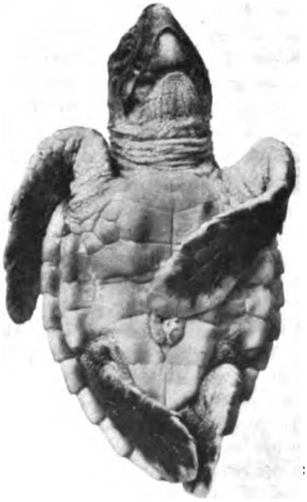


Fig. 2

Fig. 1. Dorsal View of a Young Loggerhead Turtle in a Horizontal Position, Resting Pose

About natural size

Fig. 2. Ventral View of a Young Loggerhead Turtle With the Left Side Down

The righting movement is being carried out by the left anterior flipper. About natural size.

If this is so, it is reasonable to ask through what sensory channels are they excited. The organs which from this standpoint are most likely to be concerned are the cutaneous organs of touch, the eye, and the ear. The fact that while the turtle is supported in the air between the fingers of the experimenter, a simple movement which will put it now sidewise, now ventral side up and so on is sufficient to call forth a complete and characteristic change in its type of locomotion shows that touch, which must remain essentially constant in all these shifts, has little or nothing to do with the instinctive excitations.

If a band of thin black silk is tied around the head of a young turtle so as to close its eyes, all the characteristic locomotor responses occur on changing the position of its body as they do when the eyes are open. This experiment leads to the conclusion that the eyes are not essential to these movements, a conclusion supported by the observation that the movements occur with perfect precision when the turtle is held and turned in a completely dark room. This was tested in a photographic darkroom where a young turtle was held in various positions in one hand and its locomotor movements for each given position were judged by touch with the other hand.

It is clear from these observations that neither touch nor sight is essential to the locomotor movements of the turtle. Hence the internal ear remains as the likely organ. By means of a very narrow knife-blade the internal ear of the young loggerhead turtle can be destroyed through a small aperture in the head of the animal. After this operation had been carried out on three such animals, it was found that the types of swimming and righting movements already described were completely disorganized so far as their relation to position was concerned. When placed in an aquarium the operated turtles commonly exhibited violent rotary movements, in reality a continuous righting movement which did not cease when the animal reached a horizontal position. Such an animal could be held sidewise without exciting a righting reaction and irregular righting movements were carried out at times when the animal was in a balanced position. In consequence of these observations I conclude that in the young loggerhead turtle normal position and the types of locomotion concerned with maintaining it are dependent for their sensory impulses upon the ear rather than upon the eye or the organs of touch.

REFERENCE

Parker, G. H. 1922 The crawling of young loggerhead turtles toward the sea. Jour. Exp. Zoöl., vol. 36, pp. 323–331.

THIS NUMBER COMPLETES VOL. II

VOLUME II DECEMBER, 1922 NUMBER 6

THE JOURNAL
OF
COMPARATIVE PSYCHOLOGY

Continuing Psychobiology and the
Journal of Animal Behavior

EDITED BY

KNIGHT DUNLAP
Johns Hopkins University

AND

ROBERT M. YERKES
National Research Council

IN ASSOCIATION WITH

MADISON BENTLEY
University of Illinois

HARVEY CARR
University of Chicago

WALTER B. CANNON
Harvard University

RAYMOND DODGE
Wesleyan University

SHEPHERD I. FRANZ
Government Hospital for the Insane

GILBERT V. HAMILTON
Santa Barbara Clinic,
Santa Barbara, California

SAMUEL J. HOLMES
University of California

WALTER S. HUNTER
University of Kansas

HERBERT S. JENNINGS
Johns Hopkins University

GEORGE H. PARKER
Harvard University

EDWARD L. THORNDIKE
Columbia University

MARGARET F. WASHBURN
Vassar College

JOHN B. WATSON
New York City

WILLIAM M. WHEELER
Harvard University

PUBLISHED BI-MONTHLY BY
WILLIAMS & WILKINS COMPANY
BALTIMORE, U. S. A.

Entered as second-class matter April 4, 1921, at the post office at Baltimore, Maryland, under the act of March 3, 1879

Price per volume, net postpaid
$5.00, United States, Mexico, Cuba
$5.25, Canada
$5.50, other countries

Made in United States of America

Published, January, 1923

Two Important Volumes

Volume I
EUGENICS, GENETICS AND THE FAMILY
Volume II
EUGENICS IN RACE AND STATE
FOR
The Second International Congress of Eugenics

Committee on Publication
CHARLES B. DAVENPORT, Chairman
HENRY FAIRFIELD OSBORN, Ex Officio
CLARK WISSLER
H. H. LAUGHLIN, Secretary

The Congress brought together in New York in September, 921, four hundred of the leading students of heredity, of statis-ics, of anthropology, and of eugenics from the United States, ngland, France, the Scandanavian countries, Italy, Czecho-Slovakia, and South American countries.

One of the world's great paleontologists, geologists and iologists spoke to the Congress: "I doubt if there has ever been moment in the world's history when an international conference n race character and betterment has been more important." The presence of so many leaders resulted in the presentation of HE MOST IMPORTANT PAPERS ON EUGENICS AND HEREDITY HAT HAVE YET APPEARED.

These papers will be published in two volumes, splendidly llustrated. No less that fifty illustrations of Exhibits, about wenty-five to each volume, will appear. The genetic and nthropological papers naturally fall into one group—*Eugenics, enetics and the Family.* The papers on genealogy and applied enetics will appear under the title—*Eugenics in Race and State.* hose desiring a broad foundation for eugenics will want both volumes. Those desiring merely a special group of papers can obtain such papers in a single volume.

The volumes will be printed in such a way as to reflect credit upon the Congress and the science with which it deals. Printed on a fifty per cent rag paper, light natural color, bound in blue linen weave book cloth and stamped in gold. The illustrations will be printed on a special coated paper that matches in *color* the text paper. Size: 6 x 9 inches. About 400 to 450 pages to each volume. Over fifty papers to each volume.

If you are interested in Wells' "The Outline of History," Van Loon's "The Story of Mankind," or Osborn's "Men of the Old Stone Age," then you will read with a great deal of pleasure *EUGENICS, GENETICS AND THE FAMILY* and *EUGENICS IN RACE AND STATE.* NO WORK OF SUCH INTEREST AND THOROUGHNESS HAS APPEARED FOR MANY YEARS. The volumes ARE REPRESENTATIVE OF THE MOST MODERN KNOWLEDGE of the principal American, British, French and Scandinavian biologists and sociologists, and will be in wide demand.

Pre-Publication Prices, net, postpaid
for United States

Both Volumes............ { Pre-Publication $9.00
After Publication 11.00

Single Volume........... { Pre-Publication 5.00
After Publication 6.00

For Canada, add 50 cents a volume. For other countries, add $1.00 a volume.
May be ordered from your own bookseller or order direct from the publisher.

WILLIAMS & WILKINS COMPANY
IOUNT ROYAL AND GUILFORD AVENUES
ALTIMORE, MARYLAND

entlemen:
Enter my order for the volume(s) checked below:

heck olume ou Wish
☐ Volume I—EUGENICS, GENETICS AND THE FAMILY
☐ Volume II—EUGENICS IN RACE AND STATE

Both Volumes....... { Pre-Publication $9.00 / After Publication 11.00
Single Volume....... { Pre-Publication $5.00 / After Publication 6.00

When you make the shipment, mail me a statement, at price above noted, which I will pay. (Terms 0 days.)

SIGNED ....

ADDRESS ....

THE EFFECTS OF CIGAR AND CIGARETTE SMOKING ON CERTAIN PSYCHOLOGICAL AND PHYSIOLOGICAL FUNCTIONS[1]

ROBERT LEE BATES

From the Psychological Laboratory of the Johns Hopkins University

II. BLOOD PRESSURE AND HEART RATE

Attempts have been made by several investigators to measure the effects of tobacco smoking upon systolic and diastolic pressure. In such investigations, the number of measurements are usually too small to give reliable results, in some cases a single determination of systolic pressure being made before smoking, and a single determination after smoking. Consideration of the various causes which operate in establishing and varying blood pressure indicates that such investigations are unreliable, and that although the conclusions might in some cases be true, the evidence does not warrant them.

As has been already pointed out by Carver,[2] the method of investigation of blood pressure changes developed by Dunlap and Bagby, and subsequently used in the physiological branch of the Air Medical Service, is quite applicable to problems such as those of tobacco smoking. This method consists in making a reading, with a clinical sphygmomanometer, every two or three minutes, over a prolonged interval. A well trained examiner may readily make sufficiently accurate readings of both systolic and diastolic pressure every two minutes, and in the intervening periods, may make counts of heart rate. In this procedure, a blood-pressure reading is commenced on the first, third, fifth and so on, minutes. The systolic and diastolic pressures are determined in from thirty to forty seconds, and the arm bandage is then immediately deflated, and remains deflated until the beginning of the next reading. In this way, no deleterious effect on the circulatory system is produced, as would be the case if the bandage were kept continuously inflated. The bandage is easily kept in place throughout the test, even for several hours, so that no time is lost in adjustment.

---

[1] The first installment of this contribution appeared in the October, 1922, number of this Journal.

[2] Journal of Comparative Psychology, vol. II, no. 4, pp. 279–302.

This method seems as close an approximation to the method commonly employed in recording the blood pressure of dogs and other animals, as can be made on the human reactor. In this way, the courses of the systolic and diastolic pressures are followed and both the general levels and fluctuations are observed. If only a few observations are made, it is not known whether the measurements obtained represent the general level, or fluctuations due to various causes—such fluctuations as are the rule rather than the exception—or unusual levels due to preceding conditions.

In the work here reported, the pressure determinations were made every three minutes, instead of every two, for reasons which will appear later. It is probable that for experimental work of this kind the three-minute system is quite adequate, although in cases where the patient is being subjected to adverse conditions, such as asphyxiation, and the purpose of the blood pressure readings is to protect him from syncope, the two-minute readings afford a greater measure of safety.

Six reactors were employed in these tests, all being students in the Johns Hopkins University.[3] All but one were men. Each reactor came to the laboratory, on the average of twice a week, such time or hours being arranged as would not conflict with the class schedules. Upon reaching the laboratory, the reactor was comfortably seated in a semi-reclining position in a regulation barber's chair (fig. 17). It was in this position that all blood pressure and heart rate readings were made. Twenty to twenty-five minutes of rest in the chair were allowed each subject before tests were begun. This was done to minimize such effects as might result from the exertion of coming to the laboratory, or of other recent activity. During the rest-period and thereafter until the conclusion of the test, the reactor did nothing except engage in commonplace conversation with the examiner. This was considered desirable in that the reading of books, articles, or other literature might vary the emotional tension, while the attempt to have the reactor "do nothing" during both rest-period and test-period gives no reliable control. By conversing, the examiner could control the reactor's conversation, and therefore, to some extent, his thoughts.

---

[3] The daily records of sleep and activities of the reactors are not presented here. Such records are highly important, if they are not only accurate but comprehensive. The records presented in tables 1–19, part I, of this report, are merely outlines of what ought to be obtained, and without which work of this character can not be considered to be really complete. Satisfactory records of the daily life of reactors are, however, manifestly unattainable unless the reactors are kept under controlled living conditions and practically under continuous observation; and this is possible only with provision and expenditure which are beyond the reach of the experimenter under usual conditions.

At the expiration of the rest period, blood pressure and heart rate readings were taken every three minutes with the omission of the ninth and the twentieth times, in which a free association test was conducted. The details of this will be described later (part III). Approximately two hours elapsed from the time the reactor reached the laboratory until he left the chair.

All blood pressure readings were made from the left arm with the exception of reactor 10. The right arm was used in this instance because the index of systolic pressure in this reactor was more definite in the right arm. The method of taking blood pressure in these tests was the usual one, approximately as described in the manual published for the Taylor Instrument Company to accompany their instrument known as the "Tycos" sphygmomanometer. The auscultation method was employed, and readings were made according to the "silence to silence" criterion, the fifth phase or "disappearance of all sound" being regarded as the diastolic index.

While this method is not recommended for clinical purposes, it is obviously the best for experimental work of this character, because it is more objective. If the usual criterion for the diastolic pressure is used by one examiner, he will obtain results slightly different from those obtained by other examiners, unless all are trained together with the multiple-tube stethoscope.

The method employed gives results which would have been obtained by any competent examiner, with acute hearing, using the same method. The diastolic readings are all slightly lower than the average reading which might have been obtained by the other method, but since the relative, and not the absolute, measurements are important in this work, this is of no consequence. The greater objectivity and reliability of the method employed is important, however.

In estimating the heart rate, a count was made for fifteen seconds, and the result multiplied by four, to give rate per minute. No attempt was made to observe the character of the heart action.

The room temperature was kept fairly constant, the average being 70° for all subjects except reactor 2, for whom it was 69°, on account of the fact that the reactor came early in the morning. The temperature fluctuations did not exceed 3° above or below these averages in any case.

In each test, the reactor smoked one cigar or three cigarettes, commencing immediately after the twelfth blood pressure had been taken. As it was impossible to control the rate of smoking, without the introduction of psychological factors which might influence the blood pressure, the reactor was allowed to smoke until he had finished the cigar or the three cigarettes, as far as they could conveniently be smoked. No reactor at any time finished smoking before the nineteenth time-point, and no one smoked at any time beyond the twenty-sixth time-point. The time of cessation of smoking was recorded in each case. The stubs of the cigars and cigarettes were measured, and the approximate amount of each burned estimated by the method described in the first part of the report. The amounts consumed by each reactor in each day are given in table 20. The test continued for ten days with each reactor.

The procedure in the tests may be summarized as follows:

1. Arrival at the laboratory, 20 minutes rest in the chair.
2. Commencement of the blood pressure routine measurements: readings every three minutes until 8 readings had been taken (24 minutes).

3. Free association test, in place of the ninth reading (3 minutes).

4. Continuation of the blood pressure routine for three more readings (9 minutes).

5. Smoking commenced, cigar or cigarettes, and continued until one cigar or three cigarettes were consumed.

6. Fourteen more blood pressure readings taken (42 minutes).

7. Second free association test, in place of the twenty-seventh reading (3 minutes).

8. Three more blood pressure readings (9 minutes).

Total duration, 1 hour, 50 minutes: of blood pressure record, 1 hour, 30 minutes.

On two days of reactor 2, this procedure was not quite completed. On several days with different reactors, one or two extra readings were taken at the end of the period. The averages, however, are made for thirty readings only. In the case of reactor 10, unfortunately, the second free association test was on four days given at the twenty-eighth period instead of the twenty-seventh, which makes the average for both the twenty-seventh and twenty-eighth periods with this reactor unimportant.

The daily readings for each of the reactors are given in tables 21 to 26 inclusive. In each table the first column gives the actual time of day at which the three minute periods began. The second column gives the systolic pressure in millimeters of mercury; the third column gives the diastolic pressure; the fourth column gives the pulse-pressure, *i.e.*, the difference between the systolic and diastolic; and the fifth column gives the heart rate in beats per minute. In each case the heart rate was taken immediately after the systolic and diastolic readings. The blood pressure readings were made within the interval of a minute following the period for which the time is indicated: the pulse rate within the period of a minute and a half.

Certain uniform tendencies are discoverable in the results of the six subjects, and to make these tendencies more apparent, tables 27 to 32 inclusive, and figures 10 to 15 inclusive were prepared. In these tables are given the average readings of blood pressure and heart rate for each reactor for all ten days.

In these tables, for each subject, the first column presents, in order, the averages of the first reading on each of the ten days, the averages of the second reading, the averages of the third reading, and so on. Similar averages for diastolic and pulse pressure, and for the heart rate are given. These averages are plotted for each reactor in figures 10 to 15. The blood pressure readings are plotted in each case in millimeters of mercury, and the heart rate in beats per minute, the numerical values being indicated at the left of the charts. The gaps at A and B are the periods of the free association tests. The plus mark indicates the beginning of smoking, and the short vertical line the limits within which smoking ceased on the several days.

In every case, the systolic and diastolic pressures and the heart rates show an upward tendency shortly after the beginning of smoking, with a return towards "normal" with the cessation of smoking. The pulse pressures, indicated in the diagram by the difference between the systolic and diastolic graphs, are less uniform. The average rise is small in each case, but the uniformity might be significant.

The significance of variation in average readings, such as are presented in tables 27 to 32, and figures 10 to 15 can not in any case be determined from the averages alone. Nothing could be more fallacious than the assumption from these tables and diagrams alone, of a real and important effect of tobacco smoking upon blood pressure and heart rate. Not only the importance, but even the actuality of such an effect, must be determined by a further study of the detailed data. An average has only mathematical significance in any case until further significance has been demonstrated. Not only may averages, when taken alone. fail to show tendencies which are actually shown clearly in the data averaged, but in certain historical cases, tendencies apparently shown by averages have been completely absent from the data from which the averages were drawn.

In many cases the mean variation (average deviation) of averages furnishes accessory data which indicate the significance of the averages. In the case under consideration, this mean variation would be misleading, as will be pointed out below.

The methods of studying the detailed data are exemplified in figure 16. In this figure, the daily systolic readings of reactor 2 are plotted on the same axes: or rather, since the ten curves when superposed are not easily traceable unless colors are used, the values are plotted in two groups, the reading for the first five days in the first group, and the reading for the second five days in the second group. The axes are, however, the same in the two groups.

From a study of the systolic pressure readings of reactor 2, as given in table 21 or figure 16, several things are clear. First, there is great daily variation, in magnitude much greater than the maximal variation in the average readings of table 27 and figure 10. Second, in spite of these fluctuations, the tendency of the averages (table 27 and figure 10), is actually present in the measurements of days 3, 4, 6, 7, 8, 9, and 10, and there is nothing in the data of the other three days to indicate that the same tendency may not be present, but masked by the fluctuations due to other causes. Third, the temporal variations in these assumed tendencies, and the different average value of the pressure from day to day, make the mean variation which might be computed for each average of tables 27 to 32 of no significance.

The study of the data of tables 21 to 26 in detail is a tedious matter, and the presentation of the one hundred and eighty curves is not possible. The reader may either accept the author's conclusion that in the case of each of the six reactors the general tendency shown in figures 27 to 32 is actually present, and that these figures, while not demonstrating the tendency, nevertheless illustrate it: or he may check up the conclusion from the data of tables 21 to 26.

The importance of the apparent general effect of tobacco smoking upon blood pressure and heart rate, is a matter requiring separate consideration. Admitting the occurrence of a cardiovascular adjustment occasioned by smoking, we must compare it with cardio-vascular adjustments, due to other causes which, as is clearly shown by figure 16 and by the tables, are going on concurrently. Although the effects of smoking apparently vary from day to day, they are not in general as large as those due to the other causes, and, manifestly, other causes must be at work to produce the apparent difference in the smoking effects, either by actually modifying the tobacco effect, or by an addition or subtraction of effects.

The variable causes at work are presumably of two sorts; (a) "physiological," that is: variation in bodily metabolism due to the state of health, digestion, etc., (b) "psychological," that is: variation in the stimulation from the environment and the consequent perceptual, ideational and emotional reactions. While the causes of the first class may account in part for the average daily levels, and may modify the effects of smoking, and of the psychological factors, the latter are probably the most important in these cases.

It may be assumed that some of the irregular variations were due to the fact that the reactor was not kept in absolute quiet, but that conversation was allowed, controlled by the experimenter. While the actual fluctuations are undoubtedly affected by the conversation, through the intellectual and emotional activities introduced, the fluctuations are no greater than are obtained under conditions where speech is not allowed. Investigations in this laboratory have shown that under the latter conditions, the irregular fluctuations are just as large as in the present data. Furthermore, when the reactor is kept in absolute quiet, the psychological conditions are actually more variable, varying from somnolence to intense ideational activity. The conditions under which these records were taken may, therefore, fairly be claimed to be the more "normal," although it is highly desirable that the effects of smoking, during periods of drowsiness, periods of sustained emotional excitement, and periods of mental and physical work, should later be investigated.

The irregular fluctuations in blood pressure from moment to moment under the ordinary conditions of experiment, shown clearly in tables 21 to 26, and in figure 16, explain the futility of the attempts to do experimental work with isolated or occasional readings. A single blood pressure reading before commencing to smoke, and a second reading a fixed number of minutes later, may show a rise in some subjects and a fall in others, although all may really react in the same general way. In working with untrained reactors, to whom the mere technique of the readings may be exciting, artifactual results may readily be obtained. It is probable, in the light of these records, and others obtained by the same method of prolonged series of readings, that the application of this method to other problems, especially to the problems of fatigue and work, and to the problem of the cyclic sexual variation in women, not only will give reliable results where none are obtainable by the method of occasional readings, but will also reveal unsuspected features of cardio-vascular adjustment.

The immediate rise in blood pressure and in heart rate produced by smoking is not so far shown to be due to the absorbed smoke-products. The psychological activities involved in the smoking process are without doubt important. We do not yet know, for example, what general effect upon blood pressure would be produced if the reactor, previously unoccupied, were caused to cut out paper-dolls for a period of time comparable to that occupied by smoking in these tests. In fact, we have little systematic knowledge of the relation of blood pressure changes to psychological processes, and although the obtaining of this knowledge by the general procedure used in this research is quite possible, it involves an enormous amount of time and labor, and needs a provision of funds quite beyond those we are able to obtain at present.

It was thought possible to obtain some check on the psychological factor by causing reactors to go through the smoking process without obtaining the usual tobacco products. Experiments with "denatured" tobacco showed at once that reactors with even a slight acquaintance with tobacco immediately detected the fraud, and the possibility of substituting warm air for smoke, with reactors of the grade of intelligence we used, is clearly zero. These methods of control were therefore not undertaken.

The results of this part of the investigation may be summarized as follows:

The effects, on healthy young adult reactors, of smoking a cigar or three cigarettes, are to produce a rise in systolic and diastolic blood pressure, and in heart rate. This rise varies in amount and in rapidity, from reactor to reactor, and from day to day for the same reactor. The rises in blood pressure usually amount to but a few millimeters, above the previous average level, and are in almost all cases less than ten, but may in some cases be over twenty millimeters. The rise in heart rate is irregular; less than ten per second in most cases, but may be as much as twenty. The normal irregular variations in blood pressure, due to various causes, are practically as great as the variations which may be ascribed to tobacco, but the normal variations in heart rate are less significant than the tobacco effects.

The blood pressures and heart rate subside to "normal" in from twenty to thirty minutes. In some cases this subsidence occurs before the finishing of the cigar or cigarettes: in other cases, the decline does not appear, and the rise may even be continued, for some minutes after the cessation of smoking. In other cases, the cessation of smoking is marked by an immediate decline in blood pressures and heart rate. While it seems probable that the time elapsing after the beginning of smoking is a more important factor than the discontinuance, this can not be clearly made out from the records so far obtained.

How far this effect is due to absorbed smoke-products, and how much to the psychological factors involved in the smoking process, remains to be discovered. Provision for extensive psychological work on blood pressure is urgently needed.

TABLE 20

Smoking schedules of reactors, indicating grams of tobacco consumed for each day's test

DATE	REACTOR					
	1 Cigarettes	2 Cigars	3 Cigars	4 Cigarettes	5 Cigars	6 Cigarettes
January 10	2.489					
January 11	2.178		4.114			
January 12		3.586				
January 13		4.466				
January 14				2.437		
January 15				2.489		
January 17	2.697	4.817				
January 18	2.437		4.114			
January 19		5.168				
January 20			4.114		4.114	
January 22				2.489		
January 24	2.697	4.114				
January 25	2.641					2.437
January 26					3.763	2.489
February 2						2.541
February 7	2.541	4.466				
February 8	2.489		3.763			2.541
February 9				2.593		2.645
February 10			3.412		4.114	
February 11		4.817				
February 12				2.489		
February 14	2.437	4.817				
Feburary 15	2.437		3.588			2.593
February 16				2.489		2.593
February 17			3.763		4.466	
February 18		4.992				
February 19				2.385		
February 21		4.466				
February 23						2.645
February 24			4.466		4.817	
February 25					4.114	
February 26				2.282	4.114	
March 1			3.939			2.489
March 2				2.489		2.541
March 3			3.763		4.817	
March 6				2.385		
March 8					4.817	
March 9					4.466	

TABLE 21A

Reactor 2, first day, January 10, 1921

Blood pressure, heart rate, duration of smoking period and interval for free association test

A. M. HOUR	BLOOD PRESSURE			HEART RATE
	Systolic	Diastolic	Pulse pressure	
9:17	102	60	42	72
9:20	104	60	44	68
9:23	106	62	44	68
9:26	98	62	36	64
9:29	98	62	36	64
9:32	100	60	40	66
	Free association test			
9:42	100	62	38	64
9:45	102	62	40	64
9:47	102	62	40	68
	Began smoking at 9:48			
9:50	104	62	42	64
9:53	98	64	34	64
9:56	98	64	34	60
9:59	102	62	40	64
10:02	104	64	40	64
10:05	104	64	40	64
	Ceased smoking at 10:07			
10:08	104	62	42	64
10:11	102	62	40	66
10:14	104	64	40	68
10:17	106	68	38	60
	Free association test			

TABLE 21B

Second day, January 11, 1921

8:55	112	68	44	72
8:58	110	64	46	72
9:01	110	64	46	72
9:03	110	62	48	72
9:06	106	62	44	68
9:09	104	62	42	68
9:12	108	62	46	68
9:15	106	62	44	68
9:18	Free association test			
9:21	108	62	46	68
9:24	104	62	42	68
9:27	108	62	46	68

TABLE 21B—*Continued*

A. M. HOUR	BLOOD PRESSURE			HEART RATE
	Systolic	Diastolic	Pulse pressure	
	Began smoking at 9:28			
9:30	108	62	46	64
9:33	96	60	36	64
9:36	96	62	34	72
9:39	100	62	38	66
9:42	102	62	40	64
9:45	104	62	42	64
9:48	104	64	40	76
9:51	106	66	40	72
9:54	102	62	40	76
	Ceased smoking at 9:56			
9:57	98	64	34	64
10:00	104	62	42	60
10:03	104	62	42	64
10:06	106	62	44	64
10:09	106	62	44	64
10:12	Free association test			
10:15	108	64	44	64
10:18	100	62	38	72

TABLE 21C

Reactor 2, third day, January 17, 1921

8:55	106	60	46	68
8:58	108	60	48	68
9:01	110	60	50	68
9:03	110	60	50	68
9:06	110	60	50	64
9:09	106	60	46	68
9:12	108	60	48	64
9:15	108	60	48	64
9:18	Free association test			
9:21	108	58	50	68
9:24	106	60	46	68
9:27	106	60	46	64
	Began smoking at 9:28			
9:30	108	60	48	60
9:33	108	62	46	64
9:36	106	60	46	64
9:39	108	62	46	60
9:42	106	62	44	60
9:45	110	64	46	68

TABLE 21C—*Continued*

A. M. HOUR	BLOOD PRESSURE			HEART RATE
	Systolic	Diastolic	Pulse pressure	
9:48	108	62	46	64
9:51	106	62	44	66
9:54	108	62	46	64
9:57	108	60	48	64
	Ceased smoking at 9:59			
10:00	110	64	46	64
10:03	110	66	44	66
10:06	110	64	46	68
10:09	110	64	46	64
10:12	Free association test			
10:15	112	66	46	68
10:18	110	66	44	64
10:21	112	68	44	68
10:24	110	66	44	64
10:27	108	66	42	62

TABLE 21D

Reactor 2, fourth day, January 18, 1921

8:54	106	62	44	64
8:57	106	60	46	68
9:00	108	62	46	68
9:03	110	62	48	64
9:06	108	64	44	68
9:09	108	60	48	64
9:12	106	64	42	68
9:15	104	60	44	68
9:18	Free association test			
9:21	106	58	48	68
9:24	108	62	46	70
9:27	106	62	44	68
	Began smoking at 9:28			
9:30	102	62	40	68
9:33	104	62	42	68
9:36	106	62	44	64
9:39	102	62	40	68
9:42	106	62	44	68
9:45	106	62	44	68
9:48	110	66	44	70
9:51	106	62	44	72
9:54	110	68	42	74
9:57	106	64	42	68
	Ceased smoking at 9:58			

TABLE 21D—*Continued*

A. M. HOUR	BLOOD PRESSURE			HEART RATE
	Systolic	Diastolic	Pulse pressure	
10:00	108	66	42	68
10:03	104	64	40	68
10:06	104	64	40	64
10:09	102	64	38	68
10:12	Free association test			
10:15	106	64	42	68
10:18	106	68	38	66
10:21	108	68	40	64

TABLE 21E

Reactor 2, fifth day, January 24, 1921

8:54	102	60	42	64
8:57	108	68	40	68
9:00	106	66	40	64
9:03	110	68	42	64
9:06	104	64	40	64
9:09	108	66	42	60
9:12	104	66	38	60
9:15	106	66	40	60
9:18	Free association test			
9:21	106	68	38	62
9:24	110	70	40	60
9:27	106	66	40	60
	Began smoking at 9:28			
9:30	106	68	38	68
9:33	110	70	40	68
9:36	106	70	36	64
9:39	110	70	40	60
9:42	102	70	32	64
9:45	106	72	34	62
9:48	106	74	32	64
9:51	110	72	38	60
9:54	106	72	34	64
9:57	110	74	36	64
	Discontinued smoking at 9:58			
10:00	112	74	38	62
10:03	110	72	38	62
10:06	106	74	32	60
10:09	104	74	30	62
10:12	Free association test			
10:15	110	80	30	60
10:18	108	70	38	64
10:21	108	70	38	56
10:24	108	70	38	60

TABLE 21F

Reactor 2, sixth day, January 25, 1921

A.M. HOUR	BLOOD PRESSURE			HEART RATE
	Systolic	Diastolic	Pulse pressure	
8:54	108	70	38	68
8:57	108	70	38	72
9:00	108	70	38	70
9:03	108	64	44	68
9:06	100	64	36	68
9:09	102	66	36	70
9:12	104	66	38	70
9:15	100	64	36	68
9:18	Free association test			
9:21	102	66	36	60
9:24	106	68	38	62
9:27	108	68	40	64
	Began smoking at 9:28			
9:30	104	68	36	64
9:33	104	68	36	64
9:36	104	70	34	68
9:39	106	66	40	72
9:42	108	66	42	68
9:45	104	66	36	68
9:48	108	70	38	72
9:51	106	68	38	72
	Discontinued smoking at 9:52			
9:54	108	68	40	68
9:57	106	68	38	64
10:00	104	70	34	64
10:03	100	70	30	64
10:06	100	70	30	64
10:09	106	70	36	60
10:12	Free association test			
10:15	102	66	36	64
10:18	100	70	30	56
10:21	104	70	34	60

TABLE 21G

Reactor 2, seventh day, February 7, 1921

8:54	102	58	44	68
8:57	106	58	48	72
9:00	104	60	44	72
9:03	102	58	44	72
9:06	102	60	42	72

TABLE 21G—*Continued*

A.M. HOUR	BLOOD PRESSURE			HEART RATE
	Systolic	Diastolic	Pulse pressure	
9:09	102	60	42	68
9:12	104	60	44	64
9:15	104	58	46	68
9:18	Free association test			
9:21	100	58	42	64
9:24	98	58	40	68
9:27	100	60	40	64
	Began smoking at 9:30			
9:30	102	60	42	68
9:33	100	62	38	64
9:36	102	62	40	76
9:39	102	64	38	72
9:42	106	62	44	72
9:45	102	64	38	76
9:48	104	64	40	72
9:51	106	64	42	70
9:54	104	66	38	76
	Discontinued smoking at 9:57			
9:57	106	64	42	76
10:00	100	64	36	72
10:03	98	60	38	76
10:06	98	62	36	72
10:09	102	62	40	76
10:12	Free association test			
10:15	106	60	46	70
10:18	96	60	36	76
10:21	98	60	38	68
10:24	100	60	40	72

TABLE 21H

Reactor 2, eighth day, February 8, 1921

8:54	98	62	36	62
8:57	102	64	38	60
9.00	100	64	36	60
9:03	100	62	38	60
9:06	98	64	34	64
9:09	96	64	32	58
9:12	98	64	34	58
9:15	100	64	36	64
9:18	Free association test			
9:21	96	64	32	56

TABLE 21H—*Continued*

A.M. HOUR	BLOOD PRESSURE			HEART RATE
	Systolic	Diastolic	Pulse pressure	
9:24	96	62	34	60
9:27	96	62	34	60
	Began smoking at 9:30			
9:30	94	62	32	60
9:33	102	64	38	62
9:36	100	64	36	64
9:39	100	64	36	68
9:42	104	70	34	64
9:45	98	68	30	64
9:48	100	70	30	68
9:51	100	66	34	66
9:54	100	62	38	64
	Discontinued smoking at 9:55			
9:57	96	60	36	68
10:00	92	58	34	64
10:03	96	64	32	64
10:06	100	62	38	62
10:09	96	62	34	62
10:12	Free association test			
10:15	96	64	32	60
10:18	102	64	38	60
10:21	102	64	38	60
10:24	100	64	36	56

TABLE 21I

Reactor 2, ninth day, February 14, 1921

8:55	96	60	36	68
8:58	100	60	40	68
9:01	96	60	36	64
9:04	100	62	38	68
9:07	96	60	36	64
9:10	100	62	38	68
9:13	96	60	36	66
9:16	96	60	36	64
9:19	Free association test			
9:22	98	60	38	64
9:25	98	60	38	60
9:28	98	60	38	64
	Began smoking at 9:29			
9:31	98	60	38	72
9:34	106	62	44	72

TABLE 21I—*Continued*

A.M. HOUR	BLOOD PRESSURE			HEART RATE
	Systolic	Diastolic	Pulse pressure	
9:37	104	66	38	70
9:40	104	66	42	66
9:43	102	66	44	68
9:45	106	68	38	72
9:48	106	70	36	68
9:51	102	64	38	68
9:54	104	66	38	68
	Discontinued smoking at 9:55			
9:57	100	70	30	64
10:00	100	64	36	64
10:03	98	66	32	68
10:06	98	60	38	64
10:09	96	62	34	66
10:12	Free association test			
10:15	102	62	40	68
10:18	100	62	38	64
10:21	98	64	34	72

TABLE 21J

Reactor 2, tenth day, February 15, 1921

8:55	90	56	34	64
8:58	92	58	34	64
9:01	90	58	32	64
9:04	90	58	32	60
9:07	90	58	32	68
9:10	90	58	32	64
9:13	90	56	34	60
9:16	90	58	32	64
9:19	Free association test			
9:22	90	60	30	60
9:25	90	58	32	62
9:28	96	60	36	56
	Began smoking at 9:31			
9:31	96	64	32	64
9:34	94	64	30	60
9:37	96	66	30	64
9:40	94	66	28	68
9:43	94	66	28	64
9:46	94	62	32	64
9:49	94	66	28	68
9:52	92	64	28	64

TABLE 21J—*Continued*

A.M. HOUR	BLOOD PRESSURE			HEART RATE
	Systolic	Diastolic	Pulse pressure	
9:55	96	64	32	68
9:58	96	66	30	72
	Discontinued smoking at 10:00			
10:01	100	64	36	66
10:04	96	64	32	66
10:07	90	60	30	68
10:10	90	60	30	60
10:13	Free association test			
10:16	94	60	34	60
10:19	90	60	30	60
10:22	92	58	34	62

TABLE 22A

Reactor 5, first day, January 12, 1921

Blood pressure, heart rate, duration of smoking period and interval for free association test

P.M. HOUR	BLOOD PRESSURE			HEART RATE
	Systolic	Diastolic	Pulse pressure	
2:25	110	62	48	60
2:28	110	66	44	58
2:31	114	64	50	60
2:34	116	70	46	60
2:37	114	68	46	60
2:40	114	68	46	58
2:43	114	68	46	56
2:46	112	68	44	60
2:49	Free Association test			
2:52	112	74	38	60
2:55	114	70	44	60
2:58	110	70	40	60
	Began smoking at 2:59			
3:01	112	70	42	60
3:04	118	72	46	68
3:07	116	80	36	64
3:10	118	80	38	72
3:13	122	78	44	72
3:16	122	78	44	68
3:19	122	76	46	72
3:22	122	78	46	64
3:25	124	78	46	68
3:28	136	82	54	72
	Discontinued smoking at 3:30			
3:31	124	78	46	68
3:34	126	78	48	72
3:37	130	82	48	68
3:40	124	78	46	68
3:43	Free association test			
3:46	128	78	50	76
3:49	124	78	46	72
3:52	122	74	48	64

Reactor smoked one cigar (3.58 grams of tobacco)

TABLE 22B

Reactor 5, second day, January 13, 1921

P.M. HOUR	BLOOD PRESSURE			HEART RATE
	Systolic	Diastolic	Pulse pressure	
2:25	110	72	38	60
2:28	110	68	42	60
2:31	110	70	40	60
2:34	110	72	38	62
2:37	112	70	42	60
2:40	114	70	44	62
2:43	114	72	42	60
2:46	108	70	38	60
2:49	Free association test			
2:52	112	72	40	64
2:55	110	72	38	60
2:58	110	72	38	60
	Began smoking at 2:59			
3:01	110	72	38	60
3:04	116	72	44	60
3:07	114	74	40	64
3:10	114	74	40	62
3:13	118	82	36	62
3:16	120	82	38	64
3:19	116	78	38	64
3:22	118	80	38	62
3:25	118	82	36	64
	Discontinued smoking at 3:28			
3:28	120	86	34	68
3:31	120	82	38	64
3:34	118	80	38	60
3:37	120	84	36	64
3:40	120	82	38	64
3:43	118	82	36	64
3:46	Free association test			
3:49	122	80	42	68
3:52	120	80	40	64
3:55	118	80	38	64

TABLE 22C

Reactor 5, third day, January 17, 1921

1:25	110	58	52	60
1:28	110	58	52	64
1:31	112	66	46	74
1:34	112	60	52	60
1:37	112	60	52	60

TABLE 22C—*Continued*

P.M. HOUR	BLOOD PRESSURE			HEART RATE
	Systolic	Diastolic	Pulse pressure	
1:40	110	60	50	60
1:43	112	60	52	66
1:46	112	60	52	66
1:49	Free association test			
1:52	112	58	54	60
1:55	108	60	48	66
1:58	110	60	50	64
	Began smoking at 1:58			
2:01	104	64	40	60
2:04	114	70	44	60
2:07	118	70	48	60
2:10	118	70	48	64
2:13	122	70	52	68
2:16	122	70	52	60
2:19	118	70	48	64
	Discontinued smoking at 2:20			
2:22	120	68	52	72
2:25	116	66	50	60
2:28	112	68	44	68
2:31	110	72	38	80
2:34	114	68	46	68
2:37	114	68	46	64
2:40	114	68	46	64
2:43	Free association test			
2:46	118	66	52	72
2:49	114	64	50	64
2:52	112	64	48	64

TABLE 22D

Reactor 5, fourth day, January 19, 1921

2:25	110	64	56	60
2:28	116	66	50	62
2:31	116	66	50	68
2:34	116	62	54	64
2:37	114	64	50	68
2:40	116	66	50	64
2:43	118	66	52	64
2:46	114	66	48	68
2:49	Free association test			
2:52	116	62	54	60
2:55	120	70	50	60

TABLE 22D—*Continued*

P.M. HOUR	BLOOD PRESSURE			HEART RATE
	Systolic	Diastolic	Pulse pressure	
2:58	118	70	48	64
	Began smoking at 3:00			
3:01	118	70	48	64
3:04	114	70	44	64
3:07	116	70	46	68
3:10	116	70	46	68
3:13	120	74	46	64
3:16	116	68	48	72
3:19	118	74	44	66
	Discontinued smoking at 3:20			
3:22	118	74	44	68
3:25	120	70	50	72
3:28	126	70	56	76
3:31	128	70	58	64
3:34	120	70	50	66
3:37	116	66	50	68
3:40	118	68	50	68
3:43	Free association test			
3:46	116	70	56	64
3:49	114	62	52	62
3:52	118	62	56	64
3:55	116	60	56	64

TABLE 22E

Reactor 5, fifth day, January 24, 1921

1:25	120	60	60	66
1:28	120	60	60	68
1:31	122	58	64	68
1:34	122	62	60	76
1:37	122	58	64	76
1:40	118	62	56	72
1:43	120	60	60	72
1:46	120	60	60	72
1:49	Free association test			
1:52	118	60	58	68
1:55	114	58	56	66
1:58	114	62	52	68
	Began smoking at 2:00			
2:01	118	66	52	64
2:04	120	70	50	62
2:07	120	66	54	76

TABLE 22E—*Continued*

P.M. HOUR	BLOOD PRESSURE			HEART RATE
	Systolic	Diastolic	Pulse pressure	
2:10	122	64	58	68
2:13	122	62	60	72
2:16	122	70	52	82
2:19	130	72	58	80
2:22	130	74	56	80
	Discontinued smoking at 2:25			
2:25	124	72	52	72
2:28	124	70	54	80
2:31	120	70	50	72
2:34	120	70	50	80
2:37	130	70	60	68
2:40	124	70	54	72
2:43	Free association test			
2:46	120	70	50	68
2:49	120	70	50	76
2:54	120	70	50	84

TABLE 22F

Reactor 5, sixth day, February 7, 1921

1:25	108	60	48	72
1:28	108	60	48	66
1:31	108	60	48	68
1:34	108	60	48	72
1:37	110	56	54	68
1:40	106	56	50	68
1:43	108	60	48	68
1:46	106	60	46	68
1:49	Free association test			
1:52	106	56	50	68
1:55	108	60	48	68
1:58	108	60	48	64
	Began smoking at 2:00			
2:01	106	60	46	60
2:04	110	56	54	64
2:07	108	60	48	60
2:10	108	62	46	72
2:13	112	62	50	68
2:16	112	66	46	68
2:19	112	62	50	72
2:22	112	64	48	64
2:25	114	74	40	68
	Discontinued smoking at 2:27			

TABLE 22F—*Continued*

P.M. HOUR	BLOOD PRESSURE			HEART RATE
	Systolic	Diastolic	Pulse pressure	
2:28	114	76	38	64
2:31	112	66	46	68
2:34	108	62	46	76
2:37	112	66	46	72
2:40	114	64	50	64
2:43	Free association test			
2:46	110	66	44	68
2:49	112	62	50	64
2:52	108	60	48	68

TABLE 22G

Reactor 5, seventh day, February 11, 1921

1:25	112	58	54	68
1:28	108	56	52	60
1:31	110	60	50	68
1:34	108	60	48	68
1:37	110	60	50	64
1:40	110	58	52	60
1:43	104	56	48	64
1:46	106	58	48	64
1:49	Free association test			
1:52	106	58	48	60
1:55	112	60	52	60
1:58	110	60	50	64
	Began smoking at 2:00			
2:01	110	66	44	60
2:04	112	62	50	64
2:07	112	62	50	72
2:10	116	64	52	80
2:13	118	62	56	68
2:16	116	68	48	72
2:19	122	68	54	64
	Discontinued smoking at 2:21			
2:22	120	68	52	76
2:25	110	62	48	72
2:28	110	62	48	72
2:31	112	62	50	68
2:34	112	62	50	68
2:37	110	60	50	72
2:40	116	66	50	68
2:43	Free association test			
2:46	112	62	50	68
2:49	116	58	58	72
2:52	116	60	56	68

TABLE 22H

Reactor 5, eighth day, February 14, 1921

P.M. HOUR	BLOOD PRESSURE			HEART RATE
	Systolic	Diastolic	Pulse pressure	
1:25	114	62	52	64
1:28	114	64	50	64
1:31	114	60	54	64
1:34	108	58	50	64
1:37	108	58	50	64
1:40	104	58	46	64
1:43	104	58	46	64
1:46	100	56	44	64
1:49	Free association test			
1:52	104	58	46	60
1:55	110	60	50	60
1:58	104	60	44	60
	Began smoking at 2:00			
2:01	110	66	44	72
2:04	110	64	46	62
2:07	112	68	44	68
2:10	118	68	50	66
2:13	112	68	44	64
2:16	116	68	48	64
2:19	114	68	46	64
2:22	110	66	44	62
2:25	112	70	42	72
	Discontinued smoking at 2:26			
2:28	112	70	42	64
2:31	110	66	44	60
2:34	112	62	50	64
2:37	110	64	46	62
2:40	108	62	46	64
2:43	110	64	46	60
2:46	Free association test			
2:49	114	66	48	60
2:52	110	66	44	60
2:55	114	68	46	

TABLE 22I

Reactor 5, ninth day, February 18, 1921

2:25	110	60	50	74
2:28	110	60	50	68
2:31	108	58	50	68
2:34	112	60	52	64
2:37	112	58	54	68

TABLE 22I—*Continued*

P.M. HOUR	BLOOD PRESSURE			HEART RATE
	Systolic	Diastolic	Pulse pressure	
2:40	112	60	52	68
2:43	110	60	50	72
2:46	108	58	50	68
2:49	Free association test			
2:52	110	58	52	64
2:55	106	58	48	64
2:58	104	58	46	66
	Began smoking at 3:01			
3:01	106	62	44	56
3:04	110	64	46	60
3:07	112	66	46	64
3:10	110	66	44	68
3:13	114	70	44	74
3:16	112	68	44	70
3:19	114	68	46	64
3:22	114	70	44	64
3:25	112	68	44	68
3:28	116	74	42	68
	Discontinued smoking at 3:31			
3:31	118	70	48	80
3:34	110	68	42	76
3:37	110	68	42	64
3:40	106	66	40	66
3:43	106	68	38	68
3:46	Free association test			
3:49	106	62	44	64
3:52	106	62	44	72
3:55	108	60	48	68

TABLE 22J

Reactor 5, tenth day, February 21, 1921

1:25	108	60	48	72
1:28	108	60	48	70
1:31	108	60	48	72
1:34	108	60	48	68
1:37	108	60	48	74
1:40	110	60	50	68
1:43	106	58	48	68
1:46	108	58	50	72
1:49	Free association test			
1:52	112	60	52	66

TABLE 22J—*Continued*

P.M. HOUR	BLOOD PRESSURE			HEART RATE
	Systolic	Diastolic	Pulse pressure	
1:55	106	56	50	68
1:58	104	56	48	66
	Began smoking at 2:01			
2:01	108	60	48	64
2:04	110	60	50	68
2:07	108	60	48	66
2:10	110	64	46	66
2:13	110	64	46	80
2:16	116	70	46	84
2:19	116	70	46	78
2:22	116	68	48	80
2:25	112	66	46	76
2:28	116	70	46	80
	Discontinued smoking at 2:31			
2:31	116	72	44	84
2:34	108	60	48	78
2:37	112	62	50	72
2:40	112	60	52	72
2:43	Free association test			
2:46	112	70	42	84
2:49	112	66	46	68
2:52	116	68	48	80

TABLE 23A

Reactor 6, first day, January 11, 1921

Blood pressure, heart rate, duration of smoking period and interval for free association test

P.M. HOUR	BLOOD PRESSURE			HEART RATE
	Systolic	Diastolic	Pulse pressure	
1:25	110	78	32	76
1:28	110	76	34	74
1:31	112	80	32	72
1:34	112	70	42	68
1:37	110	72	38	72
1:40	114	70	44	72
1:43	108	68	40	76
1:46	112	70	42	68
1:49	Free association test			
1:52	106	68	38	64
1:55	104	74	30	68
1:58	106	72	34	64
	Began smoking at 1:59			
2:01	108	70	38	72
2:04	108	74	34	68
2:07	110	72	38	68
2:10	110	74	36	68
2:13	110	74	36	68
2:16	108	72	36	72
2:19	110	74	36	76
2:22	110	74	36	76
2:25	110	72	38	74
	Discontinued smoking at 2:28			
2:28	110	74	36	76
2:31	108	74	34	68
2:34	108	74	34	76
2:37	110	76	34	88
2:40	110	80	30	80
2:43	Free association test			
2:46	112	74	38	76
2:49	112	76	36	80
2:52	112	76	36	68
2:55	104	68	36	68

TABLE 23B

Reactor 6, second day, January 18, 1921

P.M. HOUR	BLOOD PRESSURE			HEART RATE
	Systolic	Diastolic	Pulse pressure	
2:25	106	68	38	74
2:28	110	64	36	72
2:31	110	70	40	80
2:34	106	64	42	80
2:37	118	78	40	76
2:40	108	68	40	72
2:43	110	72	38	68
2:46	108	74	34	72
2:49		Free association test		
2:52	110	74	36	80
2:55	108	74	34	64
2:58	106	72	34	76
		Began smoking at 2:59		
3:01	106	70	36	70
3:04	108	72	36	76
3:07	108	70	38	72
3:10	114	74	40	72
3:13	116	74	42	76
3:16	112	74	38	72
3:19	112	70	42	76
3:22	112	70	42	80
3:25	112	70	42	80
3:28	114	74	40	72
3:31	112	72	40	76
		Ceased smoking at 2:30		
3:34	110	74	36	74
3:37	110	72	38	68
3:40	112	74	38	68
3:43		Free association test		
3:46	110	78	32	72
3:49	116	78	38	68
3:52	118	80	38	62

TABLE 23C

Reactor 6, third day, January 20, 1921

2:25	104	60	44	68
2:28	110	60	50	72
2:31	106	60	46	72
2:34	106	56	50	72
2:37	106	60	46	64

TABLE 23C—*Continued*

P.M. HOUR	BLOOD PRESSURE			HEART RATE
	Systolic	Diastolic	Pulse pressure	
2:40	110	62	48	80
2:43	108	64	44	64
2:46	108	60	38	72
2:49	Free association test			
2:52	108	62	46	64
2:55	106	60	46	72
2:58	108	60	48	64
	Began smoking at 2:59			
3:01	106	64	42	64
3:04	110	60	50	64
3:07	110	62	48	68
3:10	108	66	42	80
3:13	106	64	42	72
3:16	106	66	40	72
3:19	108	66	42	80
3:22	110	68	42	70
3:25	110	70	40	76
3:28	110	64	46	80
3:31	108	70	38	76
	Discontinued smoking at 3:31			
3:34	112	70	42	76
3:37	110	70	40	72
3:40	108	64	44	64
3:43	Free association test			
3:46	112	60	52	68
3:49	104	64	40	64
3:52	102	68	34	68
3:55	104	70	34	72

TABLE 23D

Reactor 6, fourth day, February 8, 1921

2:25	110	56	54	76
2:28	108	58	50	84
2:31	108	60	48	82
2:34	108	60	48	88
2:37	110	62	48	84
2:40	110	64	46	84
2:43	108	62	46	80
2:46	108	64	44	72
2:49	Free association test			
2:52	108	70	38	72

TABLE 23D—*Continued*

P.M. HOUR	BLOOD PRESSURE			HEART RATE
	Systolic	Diastolic	Pulse pressure	
2:55	108	70	38	72
2:58	110	70	40	68
	Began smoking at 3:00			
3:01	110	70	40	72
3:04	112	74	38	76
3:07	108	66	42	80
3:10	110	70	40	76
3:13	106	72	34	76
3:16	112	74	38	80
3:19	112	78	34	72
3:22	112	74	38	76
3:25	116	74	42	72
3:28	120	78	42	76
3:31	118	78	40	80
	Discontinued smoking at 3:34			
3:34	118	78	40	76
3:37	118	74	44	76
3:40	114	70	44	76
3:43	Free association test			
3:46	114	74	40	76
3:49	108	72	36	76
3:52	110	72	38	76

TABLE 23E

Reactor 6, fifth day, February 10, 1921

2:25	114	60	54	88
2:28	114	62	52	84
2:31	116	62	54	86
2:34	116	64	52	88
2:37	118	62	56	88
2:40	116	64	52	84
2:43	116	62	54	84
2:46	116	60	56	82
2:49	Free association test			
2:52	112	60	52	82
2:55	106	60	46	88
2:58	110	62	48	80
	Began smoking at 3:00			
3:01	116	60	56	76
3:04	116	60	56	76
3:07	112	60	52	84

TABLE 23E—*Continued*

P.M. HOUR	BLOOD PRESSURE			HEART RATE
	Systolic	Diastolic	Pulse pressure	
3:10	112	60	52	84
3:13	112	60	52	90
3:16	112	60	52	88
3:19	114	60	54	96
3:22	118	64	54	100
3:25	116	62	54	100
3:28	114	62	52	104
3:31	114	62	52	100
3:34	114	62	52	100
	Ceased smoking 3:35			
3:37	110	60	50	104
3:40	116	62	54	100
3:43	Free association test			
3:46	118	68	50	88
3:49	112	70	42	100
3:52	112	70	42	90

TABLE 23F

Reactor 6, sixth day, February 15, 1921

2:25	112	60	52	68
2:28	112	62	50	76
2:31	112	62	50	74
2:34	110	62	48	72
2:37	110	62	48	80
2:40	104	60	44	76
2:43	108	62	46	72
2:46	110	62	48	72
2:49	Free association test			
2:52	108	62	46	70
2:55	108	62	46	68
2:58	100	56	44	66
	Began smoking at 3:00			
3:01	110	64	46	70
3:04	104	60	44	64
3:07	108	62	46	80
3:10	104	60	44	76
3:13	106	60	46	76
3:16	106	64	42	80
3:19	106	64	42	80
3:22	106	64	42	76
3:25	112	64	48	80

TABLE 23F—*Continued*

P.M. HOUR	BLOOD PRESSURE			HEART RATE
	Systolic	Diastolic	Pulse pressure	
3:28	112	66	46	84
	Discontinued smoking at 3:30			
3:31	112	64	48	74
3:34	106	62	44	76
3:37	108	64	44	76
3:40	110	66	44	74
3:43	Free association test			
3:46	108	66	42	72
3:49	106	64	42	72
3:52	106	60	46	84

TABLE 23G

Reactor 6, seventh day, February 17, 1921

2:25	106	66	40	68
2:28	108	70	38	68
2:31	100	64	36	66
2:34	102	60	42	64
2:37	102	66	36	80
2:40	104	66	38	70
2:43	106	66	40	72
2:46	100	64	36	72
2:49	Free association test			
2:52	104	60	44	72
2:55	102	60	42	68
2:58	102	60	42	66
	Began smoking at 3:00			
3:01	102	64	38	72
3:04	100	64	36	64
3:07	104	66	38	68
3:10	104	66	38	68
3:13	104	68	36	76
3:16	106	66	40	72
3:19	106	66	40	76
3:22	106	68	38	64
3:25	108	72	36	68
3:28	110	74	36	68
	Discontinued smoking at 3:30			
3:31	108	72	36	68
3:34	108	72	36	70
3:37	106	70	36	72
3:40	104	66	38	64
3:43	Free association test			
3:46	98	64	34	76
3:49	100	64	36	72
3:52	100	64	36	64

TABLE 23H

Reactor 6, eighth day, February 24, 1921

P.M. HOUR	BLOOD PRESSURE			HEART RATE
	Systolic	Diastolic	Pulse pressure	
2:25	110	66	44	70
2:28	108	64	44	64
2:31	108	64	44	64
2:34	108	66	42	64
2:37	108	66	42	62
2:40	110	66	44	62
2:43	106	64	42	60
2:46	104	62	42	62
2:49	Free association test			
2:52	106	60	46	62
2:55	104	62	42	76
2:58	110	68	42	60
	Began smoking at 3:00			
3:01	108	62	46	72
3:04	104	62	42	64
3:07	106	64	42	72
3:10	110	64	46	68
3:13	108	66	42	76
3:16	104	62	42	64
3:19	100	58	38	76
3:22	106	62	44	76
3:25	110	64	46	72
3:28	110	66	44	68
3:31	108	70	38	72
3:34	114	72	42	72
	Discontinued smoking at 3:35			
3:37	112	64	48	68
3:40	106	64	42	62
3:43	Free association test			
3:46	106	66	40	60
3:49	106	68	38	66
3:52	106	66	40	72

TABLE 23I

Reactor 6, ninth day, March 1, 1921

2:25	110	64	46	72
2:28	108	62	46	76
2:31	110	64	46	72
2:34	108	64	44	72
2:37	108	64	44	68

TABLE 23I—*Continued*

P.M. HOUR	BLOOD PRESSURE			HEART RATE
	Systolic	Diastolic	Pulse pressure	
2:40	110	66	44	68
2:43	110	62	48	66
2:46	108	62	46	68
2:49	Free association test			
2:52	108	60	48	64
2:55	112	64	48	64
2:58	112	64	48	64
	Began smoking at 3:00			
3:01	110	66	44	72
3:04	112	64	48	66
3:07	116	68	48	64
3:10	110	66	44	70
3:13	112	72	40	80
3:16	114	72	42	76
3:19	114	72	42	72
	Discontinued smoking at 3:22			
3:22	112	72	40	64
3:25	112	62	50	62
3:28	112	64	48	68
3:31	112	62	50	74
3:34	110	64	46	72
3:37	108	64	44	74
3:40	110	70	40	68
3:43	Free association test			
3:46	112	66	46	72
3:49	108	68	40	76
3:52	108	64	44	70

TABLE 23J

Reactor 6, tenth day, March 3, 1921

1:55	116	66	50	84
1:58	116	64	52	88
2:01	116	62	54	88
2:04	118	64	54	84
2:07	114	64	50	82
2:10	114	62	52	84
2:13	118	66	52	80
2:16	110	62	48	82
2:19	Free association test			
2:22	110	60	50	80
2:25	110	60	50	84

TABLE 23J—*Continued*

P.M. HOUR	BLOOD PRESSURE			HEART RATE
	Systolic	Diastolic	Pulse pressure	
2:28	114	60	54	76
	Began smoking at 2:30			
2:31	116	64	52	78
2:34	116	66	50	82
2:37	116	68	48	78
2:40	116	66	50	78
2:43	118	68	50	74
2:46	120	70	50	86
2:49	116	70	56	80
2:52	112	70	42	84
2:55	114	70	44	88
2:58	112	66	46	84
	Ceased smoking 3:01			
3:01	114	66	48	80
3:04	112	60	52	88
3:07	114	62	52	80
3:10	112	62	50	88
3:13	Free association test			
3:16	112	64	48	78
3:19	114	62	52	88
3:22	116	62	54	84

TABLE 24A

Reactor 8, first day, January 14, 1921

Blood pressure, heart rate, duration of smoking period and interval for free association test

P.M. HOUR	BLOOD PRESSURE			HEART RATE
	Systolic	Diastolic	Pulse pressure	
2:25	100	66	34	64
2:28	100	64	36	64
2:31	100	64	36	60
2:34	102	70	32	64
2:37	102	68	34	64
2:40	100	68	32	60
2:43	100	68	32	60
2:46	100	66	34	60
2:49	Free association test			
2:52	102	68	34	56
2:55	102	68	34	60
2:58	102	68	34	56
	Began smoking at 2:59			
3:01	100	66	34	64
3:04	100	68	32	60
3:07	100	68	32	60
3:10	100	68	32	60
3:13	100	68	32	60
3:16	100	66	34	64
3:19	100	66	34	64
3:22	100	70	30	62
3:25	100	68	32	60
	Discontinued smoking at 3:27			
3:28	100	68	32	60
3:31	100	68	32	64
3:34	102	72	30	64
3:37	100	70	30	56
3:40	100	70	30	60
3:43	Free association test			
3:46	100	72	28	68
3:49	100	70	30	60
3:52	100	68	32	60
3:55	100	68	32	80

TABLE 24B

Reactor 8, second day, January 15, 1921

P.M. HOUR	BLOOD PRESSURE			HEART RATE
	Systolic	Diastolic	Pulse pressure	
2:25	100	60	40	64
2:28	100	60	40	64
2:31	100	60	40	64
2:34	100	58	42	62
2:37	100	60	40	62
2:40	100	60	40	62
2:43	106	62	44	64
2:46	102	62	40	68
2:49	Free association test			
2:52	102	62	40	68
2:55	104	60	44	66
2:58	104	60	44	66
	Began smoking at 2:59			
3:01	104	60	44	64
3:04	112	60	52	64
3:07	104	60	44	60
3:10	98	60	38	60
3:13	98	60	38	64
3:16	100	60	40	68
3:19	102	60	42	70
3:22	102	60	42	68
3:25	104	62	42	68
	Discontinued smoking at 3:26			
3:28	106	62	44	64
3:31	104	68	36	62
3:34	106	68	38	68
3:37	108	68	40	64
3:40	104	66	38	56
3:43	Free association test			
3:46	100	64	36	64
3:49	100	62	38	60
3:52	108	64	44	56
3:55	104	62	42	60

TABLE 24C

Reactor 8, third day, January 22, 1921

2:25	106	60	46	72
2:28	104	60	44	68
2:31	106	58	48	68
2:34	106	60	46	64

TABLE 24C—*Continued*

P.M. HOUR	BLOOD PRESSURE			HEART RATE
	Systolic	Diastolic	Pulse pressure	
2:37	112	60	52	64
2:40	106	60	46	68
2:43	104	60	44	68
2:46	106	60	46	68
2:49	Free association test			
2:52	104	60	44	72
2:55	106	60	46	74
2:58	104	62	42	64
	Began smoking at 2:59			
3:01	104	60	44	72
3:04	110	62	48	68
3:07	106	64	42	70
3:10	110	66	44	76
3:13	112	68	44	76
3:16	112	66	46	76
3:19	112	64	48	76
3:22	116	64	52	74
3:25	118	64	44	68
3:28	122	66	46	68
3:31	116	66	50	72
3:34	124	66	58	76
	Discontinued smoking at 3:37			
3:37	118	64	54	76
3:40	112	60	52	80
3:43	Free association test			
3:46	106	60	46	76
3:49	116	70	46	76
3:52	122	66	56	72
3:55	120	66	56	74

TABLE 24D

Reactor 8, fourth day, February 9, 1921

2:25	96	50	46	72
2:28	98	52	46	68
2:31	100	54	46	68
2:34	100	54	46	68
2:37	100	54	46	68
2:40	100	52	48	68
2:43	100	56	44	64
2:46	100	54	46	72
2:49	Free association test			

TABLE 24D—*Continued*

P.M. HOUR	BLOOD PRESSURE			HEART RATE
	Systolic	Diastolic	Pulse pressure	
2:52	100	52	48	68
2:55	96	54	42	68
2:58	98	54	44	64
	Began smoking at 2:59			
3:01	100	56	44	68
3:04	100	56	44	68
3:07	92	56	36	64
3:10	94	54	40	68
3:13	96	56	40	68
3:16	96	56	40	68
3:19	94	54	40	68
	Discontinued smoking at 3:22			
3:22	94	56	38	64
3:25	92	52	40	60
3:28	102	58	44	64
3:31	100	58	42	64
3:34	102	56	46	64
3:37	100	56	44	64
3:40	100	56	44	68
3.43	Free association test			
3:46	90	58	32	76
3:49	88	58	30	60
3:52	92	60	32	68

TABLE 24E

Reactor 8, fifth day, February 12, 1921

2:25	90	52	38	68
2:28	94	56	38	64
2:31	100	58	42	64
2:34	100	58	42	68
2:37	92	58	34	62
2:40	102	58	44	76
2:43	90	56	34	64
2:46	98	58	40	64
2:49	Free association test			
2:52	92	56	36	64
2:55	92	56	36	64
2:58	94	58	36	62
	Began smoking at 2:59			
3:01	86	56	30	62
3:04	90	56	34	60

TABLE 24E—*Continued*

P.M. HOUR	BLOOD PRESSURE			HEART RATE
	Systolic	Diastolic	Pulse pressure	
3:07	94	58	36	60
3:10	102	60	42	64
3:13	94	58	36	64
3:16	94	58	36	62
3:19	100	60	40	68
3:22	90	56	34	66
3:25	90	56	34	68
3:28	100	58	42	60
3:31	92	56	36	60
	Discontinued smoking at 3:32			
3:34	102	62	40	64
3:37	100	60	40	60
3:40	102	60	42	60
3:43	Free association test			
3:46	100	62	38	72
3:49	90	58	32	60
3:52	90	58	32	64

TABLE 24F

Reactor 8, sixth day, February 16, 1921

2:25	90	56	34	64
2:28	94	56	38	70
2:31	88	56	32	64
2:34	90	54	36	62
2:37	90	56	34	72
2:40	92	56	36	62
2:43	92	56	36	64
2:46	90	56	34	64
2:49	Free association test			
2:52	90	56	34	72
2:55	92	56	36	68
2:58	92	56	36	60
	Began smoking at 3:01			
3:01	92	56	36	60
3:04	90	52	38	64
3:07	92	52	40	60
3:10	88	52	36	60
3:13	96	56	40	60
3:16	102	56	46	58
3:19	92	54	38	68
3:22	92	56	36	66

TABLE 24F—*Continued*

P.M. HOUR	BLOOD PRESSURE			HEART RATE
	Systolic	Diastolic	Pulse pressure	
3:25	100	56	44.	64
3:28	92	58	34	64
	Discontinued smoking at 3:31			
3:31	88	54	34	62
3:34	88	56	32	60
3:37	88	54	34	64
3:40	88	56	32	60
3:43	Free association test			
3:46	92	56	36	60
3:49	90	54	36	60
3:52	88	54	34	60

TABLE 24G

Reactor 8, seventh day, February 19, 1921

2:25	90	50	40	60
2:28	90	52	38	60
2:31	90	50	40	60
2:34	90	52	38	62
2:37	96	54	42	64
2:40	90	54	36	60
2:43	90	54	36	60
2:46	90	54	36	64
2:49	Free association test (omitted)			
2:52	94	54	40	60
2:55	90	60	30	60
2:58	90	58	32	60
	Began smoking at 3:00			
3:01	94	60	34	60
3:04	94	60	34	60
3:07	94	60	34	60
3:10	92	62	30	62
3:13	90	62	28	62
3:16	96	64	32	62
3:19	100	64	36	60
3:22	92	62	30	60
3:25	102	62	40	60
3:28	100	64	36	60
3:31	100	60	40	60
3:34	102	60	42	60
	Discontinued smoking at 3:34			
3:37	96	58	38	60

TABLE 24G—*Continued*

P.M. HOUR	BLOOD PRESSURE			HEART RATE
	Systolic	Diastolic	Pulse pressure	
3:40	98	58	40	64
3:43	Free association test (omitted)			
3:46	96	56	40	64
3:49	94	56	38	60
3:52	94	58	36	60

TABLE 24H

Reactor 8, eighth day, February 26, 1921

2:25	100	60	40	72
2:28	100	60	40	76
2:31	102	60	42	76
2:34	102	60	42	72
2:37	102	60	42	76
2:40	102	60	42	80
2:43	100	60	40	76
2:46	100	60	40	76
2:49	Free association test			
2:52	102	60	42	72
2:55	98	58	40	68
2:58	100	56	44	68
	Began smoking at 3:00			
3:01	102	60	42	68
3:04	106	60	46	72
3:07	110	58	52	72
3:10	104	60	44	66
3:13	108	62	46	68
3:16	110	62	48	68
3:19	108	60	48	66
3:22	108	62	46	64
3:25	108	62	46	60
3:28	106	62	44	64
3:31	100	62	38	68
3:34	106	58	48	64
3:37	106	60	46	68
	Discontinued smoking at 3:38			
3:40	108	60	48	64
3:43	Free association test			
3:46	100	58	42	68
3:49	106	64	42	64
3:52	100	58	42	64

TABLE 24I

Reactor 8, ninth day, March 2, 1921

P.M. HOUR	BLOOD PRESSURE			HEART RATE
	Systolic	Diastolic	Pulse pressure	
2:25	94	54	40	68
2:28	96	56	40	64
2:31	100	58	42	70
2:34	100	60	40	70
2:37	106	58	46	68
2:40	106	58	48	68
2:43	102	58	44	72
2:46	106	68	48	72
2:49	Free association test			
2:52	100	58	42	68
2:55	100	58	42	68
2:58	100	60	40	72
	Began smoking at 3:00			
3:01	102	60	42	72
3:04	108	62	44	68
3:07	110	60	50	64
3:10	106	60	46	74
3:13	112	62	50	68
3:16	110	60	50	80
3:19	112	60	52	68
3:22	110	62	48	66
3:25	110	58	52	68
	Discontinued smoking at 3:27			
3:28	112	62	50	68
3:31	106	56	50	66
3:34	104	58	46	66
3:37	106	60	46	60
3:40	110	60	50	64
3:43	Free association test			
3:46	102	58	44	64
3:49	110	64	46	72
3:52	106	62	44	64

TABLE 24J

Reactor 8, tenth day, March 5, 1921

2:25	102	58	44	72
2:28	102	58	76	76
2:31	102	58	44	70
2:34	102	58	44	70
2:37	102	58	44	72

TABLE 24J—*Continued*

P.M. HOUR	BLOOD PRESSURE			HEART RATE
	Systolic	Diastolic	Pulse pressure	
2:40	102	58	44	72
2:43	102	60	42	72
2:46	104	58	46	72
2:49	Free association test			
2:52	94	56	38	72
2:55	92	58	34	72
2:58	98	58	40	66
	Began smoking at 3:00			
3:01	104	60	44	64
3:04	98	60	38	68
3:07	104	60	44	68
3:10	100	62	38	70
3:13	100	62	38	62
3:16	102	62	42	70
3:19	106	64	42	72
3:22	104	62	42	64
3:25	102	64	38	66
	Discontinued smoking at 3:28			
3:28	98	62	36	68
3:31	94	62	32	68
3:34	96	62	32	68
3:37	100	62	38	68
3:40	96	64	32	64
3:43	Free association test			
3:46	98	58	40	68
3:49	98	60	38	66
3:52	98	62	36	66

TABLE 25A

Reactor 9, first day, January 20, 1921

Blood pressure, heart rate, duration of smoking period and interval for free association test

A.M. HOUR	BLOOD PRESSURE			HEART RATE
	Systolic	Diastolic	Pulse pressure	
9:55	106	70	36	68
9:58	110	70	40	62
10:01	110	70	40	64
10:04	106	70	36	64
10:07	108	68	40	64
10:10	108	70	38	72
10:13	106	68	38	64
10:16	106	70	36	64
10:19	Free association test			
10:22	106	70	36	64
10:25	108	70	38	68
10:28	106	70	36	64
	Began smoking at 10:30			
10:31	108	70	38	64
10:34	114	76	38	68
10:37	110	70	40	60
10:40	110	76	34	60
10:43	110	70	40	68
10:46	110	70	40	68
10:49	110	76	34	68
10:52	112	76	36	76
10:55	108	72	36	72
10:58	112	78	34	64
	Discontinued smoking at 10:59			
11:01	106	70	36	68
11:04	108	70	38	64
11:07	110	72	38	64
11:10	106	74	32	72
11:13	Free association test			
11:16	106	74	32	64
11:19	106	74	32	62
11:22	108	80	28	64

TABLE 25B

Reactor 9, second day, January 26, 1921

A.M. HOUR	BLOOD PRESSURE			HEART RATE
	Systolic	Diastolic	Pulse pressure	
9:55	110	70	40	76
9:58	110	70	40	72
10:01	108	70	38	68
10:04	110	70	40	72
10:10	100	68	32	72
10:13	102	68	34	72
10:16	104	68	36	68
10:19	Free association test			
10:22	110	70	40	76
10:25	110	70	40	70
10:28	110	72	38	76
	Began smoking at 10:30			
10:31	110	70	40	66
10:34	108	72	36	66
10:37	104	70	34	70
10:40	104	70	34	74
10:43	104	72	32	70
10:46	104	74	30	72
10:49	102	72	30	70
10:52	104	74	30	68
10:55	110	72	38	66
10:58	106	76	30	64
11:01	106	78	28	66
11:04	108	78	30	64
11:07	110	76	34	70
	Discontinued smoking at 11:09			
11:10	110	80	30	72
11:13	Free association test			
11:16	104	72	32	72
11:19	104	76	28	68
11:22	106	72	34	76

TABLE 25C

Reactor 9, third day, February 10, 1921

9:55	108	66	42	80
9:58	108	64	44	80
10:01	106	62	44	84
10:04	104	64	40	84
10:07	104	64	40	80
10:10	108	66	42	80

TABLE 25C—*Continued*

A.M. HOUR	BLOOD PRESSURE			HEART RATE
	Systolic	Diastolic	Pulse pressure	
10:13	106	66	40	80
10:16	106	64	42	84
10:19	Free association test			
10:22	104	64	40	76
10:25	102	64	38	80
10:28	100	62	38	80
	Began smoking at 10:30			
10:31	106	66	40	80
10:34	106	68	38	76
10:37	104	66	38	80
10:40	108	66	42	76
10:43	104	66	38	70
10:46	102	66	36	76
10:49	106	66	40	76
10:52	104	66	38	76
10:55	102	66	36	76
10:58	106	70	36	76
11:01	100	66	34	80
	Discontinued smoking at 11:03			
11:04	104	68	36	84
11:07	106	70	36	80
11:10	102	70	32	76
11:13	Free association test			
11:16	100	70	30	72
11:19	102	70	32	72
11:22	102	74	28	72

TABLE 25D

Reactor 9, fourth day, February 17, 1921

9:55	112	62	50	76
9:58	114	60	54	70
10:01	106	62	44	72
10:04	106	62	44	72
10:07	106	62	44	68
10:10	104	62	42	76
10:13	104	60	44	64
10:16	104	60	44	66
10:19	Free association test			
10:22	102	60	42	60
10:25	106	60	46	64
10:28	102	60	42	72
	Began smoking at 10:30			

TABLE 25D—*Continued*

A.M. HOUR	BLOOD PRESSURE			HEART RATE
	Systolic	Diastolic	Pulse pressure	
10:31	108	62	46	68
10:34	106	64	42	72
10:37	110	64	46	68
10:40	108	64	44	76
10:43	106	64	42	72
10:46	108	66	42	76
10:49	108	64	44	74
10:52	108	66	42	76
10:55	108	64	44	80
10:58	112	66	46	80
	Discontinued smoking at 11:01			
11:01	108	66	42	84
11:04	108	66	42	76
11:07	108	66	42	80
11:10	110	68	42	76
11:13	Free association test			
11:16	106	66	40	68
11:19	104	66	38	72
11:22	106	66	40	72

TABLE 25E

Reactor 9, fifth day, February 24, 1921

9:55	104	68	36	64
9:58	108	70	38	72
10:01	106	72	34	68
10:04	110	72	38	64
10:07	108	70	38	60
10:10	108	72	36	64
10:13	108	72	36	64
10:16	106	68	38	64
10:19	Free association test			
10:22	106	68	38	64
10:25	108	70	38	72
10:28	106	70	36	60
	Began smoking at 10:30			
10:31	106	72	34	60
10:34	106	72	34	68
10:37	106	70	36	72
10:40	107	70	38	66
10:43	110	74	36	70
10:46	112	76	36	64

TABLE 25E—*Continued*

A.M. HOUR	BLOOD PRESSURE			HEART RATE
	Systolic	Diastolic	Pulse pressure	
10:49	110	74	36	72
10:52	114	76	38	76
	Discontinued smoking at 10:54			
10:55	112	74	38	68
10:58	108	74	34	72
11:01	114	76	38	72
11:04	106	74	32	68
11:07	108	74	36	64
11:10	110	74	36	64
11:13	Free association test			
11:16	112	76	36	64
11:19	112	74	38	60
11:22	112	76	36	66

TABLE 25F

Reactor 9, sixth day, February 25, 1921

9:55	106	66	40	72
9:58	104	64	40	68
10:01	106	64	42	76
10:04	104	64	40	72
10:07	106	64	42	72
10:10	108	64	44	68
10:13	106	64	42	80
10:16	104	64	40	74
10:19	Free association test			
10:22	104	64	40	68
10:25	104	66	38	68
10:28	100	64	36	60
	Began smoking at 10:30			
10:31	104	66	38	58
10:34	102	66	36	64
10:37	106	66	40	68
10:40	106	66	40	64
10:43	110	70	40	72
10:46	106	72	34	72
10:49	110	72	38	68
10:52	108	70	38	70
10:55	106	70	36	76
10:58	108	72	36	78
	Discontinued smoking at 11:00			
11:01	110	72	38	72

TABLE 25F—*Continued*

A.M. HOUR	BLOOD PRESSURE			HEART RATE
	Systolic	Diastolic	Pulse pressure	
11:04	108	70	38	72
11:07	108	72	36	76
11:10	106	70	36	68
11:13	Free association test			
11:16	104	68	36	76
11:19	108	70	38	68
11:22	112	70	42	70

TABLE 25G

Reactor 9, seventh day, February 26, 1921

9:55	100	62	38	68
9:58	100	62	38	64
10:01	100	62	38	64
10:04	96	62	34	64
10:07	98	62	36	60
10:10	98	60	38	64
10:13	96	60	36	72
10:16	94	62	32	60
10:19	Free association test			
10:22	94	62	32	64
10:25	94	62	32	72
10:28	94	62	32	62
	Began smoking at 10:29			
10:31	100	66	34	58
10:34	100	66	34	64
10:37	100	66	34	68
10:40	102	66	36	68
10:43	100	68	32	66
10:46	100	66	34	68
10:49	100	66	34	66
10:52	98	68	30	68
10:55	100	66	34	66
10:58	96	66	30	68
11:01	100	66	34	68
	Discontinued smoking at 11:02			
11:04	98	66	32	72
11:07	100	68	32	80
11:10	100	66	34	76
11:13	Free association test			
11:16	100	66	34	72
11:19	96	66	30	72
11:22	96	66	30	70

TABLE 25H

Reactor 9, eighth day, March 3, 1921

A.M. HOUR	BLOOD PRESSURE			HEART RATE
	Systolic	Diastolic	Pulse pressure	
9:55	108	66	42	68
9:58	106	68	38	68
10:01	108	68	40	80
10:04	112	70	52	80
10:07	112	70	52	84
10:10	110	70	50	80
10:13	110	68	42	72
10:16	112	68	44	68
10:19	Free association test			
10:22	108	70	38	76
10:25	110	72	38	66
10:28	110	72	38	68
	Began smoking at 10:30			
10:31	112	70	42	72
10:34	110	72	38	72
10:37	110	74	36	68
10:40	110	72	38	70
10:43	112	74	38	70
10:46	112	74	38	68
10:49	112	74	38	72
10:52	114	76	38	76
	Ceased smoking at 10:54			
10:55	118	78	40	72
10:58	114	78	36	72
11:01	114	70	44	72
11:04	112	70	42	76
11:07	114	70	44	76
11:10	112	70	42	68
11:13	Free association test			
11:16	116	66	50	68
11:19	116	66	50	72
11:22	112	70	42	80

TABLE 25I

Reactor 9, ninth day, March 8, 1921

p.m. 2:25	108	60	48	80
2:28	110	60	50	78
2:31	108	60	48	76
2:34	110	62	48	78
2:37	110	62	48	80

TABLE 25I—*Continued*

P.M. HOUR	BLOOD PRESSURE			HEART RATE
	Systolic	Diastolic	Pulse pressure	
2:40	106	58	48	76
2:43	108	58	50	70
2:46	102	58	44	68
2:49	Free association test			
2:52	104	58	46	78
2:55	110	62	48	80
2:58	104	60	44	72
	Began smoking at 3:00			
3:01	110	62	48	76
3:04	112	60	52	72
3:07	114	62	52	80
3:10	110	64	46	78
3:13	112	66	46	84
3:16	112	66	46	84
3:19	116	66	50	88
3:22	114	66	48	84
	Discontinued smoking at 3.24			
3:25	114	66	48	84
3:28	112	62	50	84
3:31	112	64	48	84
3:34	110	66	44	88
3:37	112	62	50	80
3:40	112	62	50	82
3:43	Free association test			
3:46	112	62	50	82
3:49	112	60	52	78
3:52	114	64	50	86

TABLE 25J

Reactor 9, tenth day, March 9, 1921

1:25	116	64	52	80
1:28	116	66	50	84
1:31	114	66	48	82
1:34	110	64	46	84
1:37	112	64	48	76
1:40	108	62	46	80
1:43	110	62	48	78
1:46	108	64	44	80
1:49	Free association test			
1:52	112	64	48	78
1:55	114	66	48	82

TABLE 25J—*Continued*

P.M. HOUR	BLOOD PRESSURE			HEART RATE
	Systolic	Diastolic	Pulse pressure	
1:58	110	64	46	80
	Began smoking at 2:00			
2:01	112	62	50	80
2:04	114	66	48	80
2:07	112	64	48	80
2:10	112	64	48	78
2:13	114	64	50	84
2:16	112	66	46	80
2:19	114	66	48	84
2:22	114	66	48	88
	Discontinued smoking at 2:23			
2:25	108	64	44	88
2:28	110	66	44	84
2:31	110	64	46	80
2:34	108	64	44	80
2:37	112	66	46	84
2:40	110	62	48	80
2:43	Free association test			
2:46	106	62	44	84
2:49	106	62	44	76
2:52	110	66	44	82

TABLE 26A

Reactor 10, first day, January 23, 1921

Blood pressure, heart rate, duration of smoking period and interval for free association test

P.M. HOUR	BLOOD PRESSURE			HEART RATE
	Systolic	Diastolic	Pulse pressure	
10:55	94	60	34	76
10:58	86	60	26	68
11:01	92	58	34	72
11:04	94	60	34	80
11:07	92	60	32	72
11:10	100	60	40	76
11:13	94	60	34	68
11:16	100	60	40	76
11:19	Free association test			
11:22	94	60	34	70
11:25	94	64	30	72
11:28	98	64	34	66
	Began smoking at 11:30			
11:31	104	68	36	68
11:34	100	60	40	74
11:37	96	62	34	72
11:40	100	60	40	76
11:43	104	66	38	72
11:46	104	60	44	76
11:49	104	64	40	76
11:52	100	60	40	76
11:55	102	60	42	76
11:58	104	64	40	72
12:01	104	64	40	72
	Discontinued smoking at 12:02			
12:04	100	68	32	70
12:07	100	66	34	72
12:10	98	60	38	72
12:13	102	60	42	72
12:16	Free association test			
12:19	96	60	36	64
12:22	96	60	36	64
12:25	96	60	36	64

TABLE 26B

Reactor 10, second day, January 26, 1921

P.M. HOUR	BLOOD PRESSURE			HEART RATE
	Systolic	Diastolic	Pulse pressure	
9:55	100	64	36	76
9:58	102	60	42	76
10:01	104	60	44	76
10:04	94	56	38	76
10:07	100	56	44	80
10:10	98	58	30	76
10:13	104	58	46	80
10:16	102	58	44	80
10:19	Free association test			
10:22	100	58	42	76
10:25	104	58	46	80
10:28	102	58	44	84
	Began smoking at 10:30			
10:31	102	56	46	78
10:34	100	60	40	80
10:37	106	60	46	80
10:40	106	62	44	80
10:43	108	62	46	80
10:46	106	64	42	80
10:49	104	62	42	80
10:52	106	66	40	80
10:55	104	68	36	82
10:58	108	64	44	84
11:01	104	64	40	84
11:04	108	66	42	80
	Discontinued smoking at 11:05			
11:07	100	66	34	80
11:10	112	70	42	76
11:13	Free association test			
11:16	110	64	46	70
11:19	104	64	40	76
11:22	108	68	40	76

TABLE 26C

Reactor 10, third day, February 2, 1921

9:55	98	60	38	68
9:58	98	60	38	72
10:01	100	60	40	74
10:04	102	60	42	76
10:07	96	60	36	76

TABLE 26C—*Continued*

A.M. HOUR	BLOOD PRESSURE			HEART RATE
	Systolic	Diastolic	Pulse pressure	
10:10	94	58	36	78
10:13	96	60	36	78
10:16	104	60	44	80
10:19		Free association test		
10:22	94	60	34	72
10:25	96	60	36	68
10:28	96	60	36	74
		Began smoking at 10:30		
10:31	104	60	44	80
10:34	106	62	44	76
10:37	110	64	46	72
10:40	102	62	40	76
10:43	100	60	40	76
10:46	102	60	42	84
10:49	110	64	46	84
10:52	110	60	50	84
10:55	100	60	40	80
10:58	100	60	40	76
11:01	104	60	44	84
		Discontinued smoking at 11:01		
11:04	100	60	40	80
11:07	106	62	44	80
11:10	94	58	36	84
11:13	102	58	44	80
11:16		Free association test		
11:19	98	56	42	76
11:22	90	60	30	84
11:25	104	60	44	76

TABLE 26D

Reactor 10, fourth day, February 8, 1921

10:55	92	62	30	72
10:58	90	62	28	76
11:01	92	62	30	70
11:04	92	62	30	76
11:07	92	60	32	72
11:10	94	60	34	68
11:13	94	60	34	72
11:16	90	60	30	70
11:19		Free association test		
11:22	86	56	30	68

TABLE 26D—*Continued*

A.M. HOUR	BLOOD PRESSURE			HEART RATE
	Systolic	Diastolic	Pulse pressure	
11:25	92	58	34	68
11:28	92	62	30	68
	Began smoking at 11:30			
11:31	100	70	30	72
11:34	90	64	26	72
11:37	90	66	24	76
11:40	90	64	26	68
11:43	92	62	30	72
11:46	92	64	28	68
11:49	90	64	26	68
11:52	92	62	30	68
11:55	94	64	30	72
11:58	94	60	34	72
12:01	86	60	26	68
	Discontinued smoking at 12:04			
12:04	90	60	30	68
12:07	84	60	24	64
12:10	82	60	22	64
12:13	88	62	26	64
12:16	Free assoication test			
12:19	88	58	30	68
12:22	90	60	30	68
12:24	86	58	28	72

TABLE 26E

Reactor 10, fifth day, February 9, 1921

9:55	92	50	42	80
9:58	90	54	36	82
10:01	90	54	36	80
10:04	86	56	30	100
10:07	90	56	34	84
10:10	94	58	36	76
10:13	92	58	34	80
10:16	92	58	34	82
10:19	Free association test			
10:22	92	52	40	74
10:25	92	56	36	76
10:28	90	56	34	74
	Began smoking at 10:30			
10:31	86	58	28	76

TABLE 26E—*Continued*

A.M. HOUR	BLOOD PRESSURE			HEART RATE
	Systolic	Diastolic	Pulse pressure	
10:34	90	56	34	76
10:37	90	52	38	80
10:40	90	50	40	80
10:43	90	50	40	84
10:46	90	52	38	84
10:49	92	54	38	80
10:52	92	58	34	76
10:55	92	56	36	80
10:58	92	56	36	76
11:01	88	56	32	76
11:04	90	56	34	76
	Discontinued smoking at 11:05			
11:07	92	58	34	76
11:10	94	60	34	80
11:13	Free association test			
11:16	90	54	36	80
11:19	90	54	36	80
11:22	86	54	32	88

TABLE 26F

Reactor 10, sixth day, February 15, 1921

p.m.				
10:55	86	50	36	68
10:58	84	50	34	70
11:01	86	52	34	68
11:04	84	56	28	66
11:07	86	54	32	68
11:10	84	56	28	64
11:13	86	54	32	68
11:16	86	54	32	64
11:19	Free association test			
11:22	86	56	30	62
11:25	84	54	30	68
11:28	86	56	30	64
	Began smoking at 11:29			
11:31	88	58	30	66
11:34	86	56	30	72
11:37	90	56	34	72
11:40	90	56	34	68
11:43	90	54	36	80
11:46	90	58	32	72
11:49	92	58	34	80

TABLE 26F—*Continued*

P.M. HOUR	BLOOD PRESSURE			HEART RATE
	Systolic	Diastolic	Pulse pressure	
11:52	90	58	32	74
11:55	92	60	32	70
11:58	90	54	36	76
	Discontinued smoking at 12:01			
12:01	92	60	32	72
12:04	82	54	28	68
12:07	90	58	32	64
12:10	90	58	32	64
12:13	Free association test			
12:16	90	56	34	68
12:19	90	58	32	64
12:22	90	58	32	68

TABLE 26G

Reactor 10, seventh day, February 16, 1921

a.m.				
9:55	90	56	34	76
9:58	88	54	34	76
10:01	90	54	36	74
10:04	90	54	36	72
10:07	90	54	36	80
10:10	92	58	34	82
10:13	92	58	34	80
10:16	90	54	36	76
10:19	Free association test			
10:22	90	54	36	74
10:25	92	54	38	68
10:28	92	54	38	68
	Began smoking at 10:30			
10:31	92	54	38	76
10:34	92	54	38	80
10:37	92	56	36	80
10:40	90	54	36	78
10:43	92	56	36	80
10:46	92	56	36	80
10:49	92	54	38	80
10:52	96	56	40	76
10:55	94	56	38	76
	Discontinued smoking at 10:58			
10:58	94	54	40	76
11:01	92	54	38	84
11:04	90	54	36	92

TABLE 26G—*Continued*

A.M. HOUR	BLOOD PRESSURE			HEART RATE
	Systolic	Diastolic	Pulse pressure	
10:07	94	54	40	80
10:10	86	54	32	76
10:13	Free association test			
10:16	90	52	38	80
10:19	86	52	34	76
10:22	90	50	40	78

TABLE 26H

Reactor 10, eighth day, February 23, 1921

9:55	94	54	40	68
9:58	96	54	42	80
10:01	92	52	40	80
10:04	92	52	40	72
10:07	92	54	38	72
10:10	90	52	38	68
10:13	92	54	38	68
10:16	92	54	38	68
10:19	Free association test			
10:22	90	56	34	72
10:25	90	54	36	80
10:28	90	54	36	76
	Began smoking at 10:31			
10:31	90	54	36	76
10:34	84	54	30	68
10:37	90	60	30	68
10:40	106	64	42	68
10:43	100	62	38	68
10:46	96	58	38	68
10:49	98	60	38	68
10:52	96	58	38	72
10:55	96	60	36	76
10:58	102	58	44	68
11:01	96	60	36	68
	Discontinued smoking at 11:04			
11:04	98	62	36	60
11:07	90	60	30	68
11:10	96	60	36	68
11:13	94	60	34	72
11:16	Free association test			
11:19	90	60	30	76
11:22	92	62	30	80
11:25	96	60	36	68

TABLE 26I

Reactor 10, ninth day, March 1, 1921

A.M. HOUR	BLOOD PRESSURE			HEART RATE
	Systolic	Diastolic	Pulse pressure	
11:15	98	62	36	64
11:18	92	62	30	66
11:21	94	60	34	68
11:24	94	60	34	64
11:27	98	62	36	62
11:30	94	60	34	64
11:33	98	62	36	68
11:36	92	64	28	68
11:39	Free association test			
11:42	96	62	34	62
11:45	96	62	34	64
11:48	92	62	30	64
	Began smoking at 11:50			
11:51	96	62	34	68
11:54	100	64	36	68
11:57	100	62	38	68
12:00	96	62	34	68
12:03	94	60	34	68
12:06	94	64	30	68
12:09	102	66	36	64
12:12	104	64	40	72
12:15	94	60	34	64
12:18	96	64	32	64
	Discontinued smoking at 12:20			
12:21	94	66	28	64
12:24	94	64	30	70
12:27	94	62	32	64
12:30	96	64	32	76
12:33	96	60	36	64
12:36	Free association test			
12:39	88	60	28	60
12:42	90	64	26	64
12:45	98	64	34	64

TABLE 26J

Reactor 10, tenth day, March 2, 1921

9:55	94	54	40	84
9:58	94	54	40	84
10:01	92	50	42	84
10:04	90	52	38	84

TABLE 26J—*Continued*

A.M. HOUR	BLOOD PRESSURE			HEART RATE
	Systolic	Diastolic	Pulse pressure	
10:07	92	54	38	88
10:10	92	54	38	82
10:13	94	54	40	84
10:16	92	54	38	80
10:19	Free association test			
10:22	90	52	38	78
10:25	90	52	38	84
10:28	90	54	36	80
	Began smoking at 10:30			
10:31	94	54	40	84
10:34	92	54	38	70
10:37	90	56	34	66
10:40	96	60	36	70
10:43	94	56	38	76
10:46	94	60	34	80
10:49	94	58	36	74
10:52	94	62	32	74
	Ceased smoking 10:54			
10:55	94	58	36	72
10:58	90	60	30	84
11:01	92	60	32	76
11:04	92	58	34	70
11:07	94	56	38	72
11:10	90	56	34	70
11:13	Free association test			
11:16	90	60	30	68
11:19	90	60	30	68
11:22	88	58	30	76

TABLE 27

Reactor 2

Averages of blood pressure and heart rate for ten days

READING	SYSTOLIC	DIASTOLIC	PULSE PRESSURE	HEART RATE
1	102.2	61.6	40.6	67.0
2	104.4	62.2	42.2	68.0
3	103.8	62.6	41.2	67.0
4	103.8	61.8	42.2	66.0
5	101.4	61.8	39.6	66.4
6	101.6	61.8	39.8	65.4
7	101.4	62.0	39.4	64.2
8	101.5	61.4	40.1	65.4
9		Free association test		
10	101.4	61.6	39.8	63.4
11	101.8	62.2	39.6	64.2
12	102.6	62.2	40.4	63.6
+		Began smoking		
13	102.2	62.8	39.4	65.0
14	102:2	63.8	38.4	65.0
15	101.8	64.6	37.2	66.6
16	102.8	64.4	38.4	66.4
17	103.4	65.0	38.4	65.6
18	103.4	65.2	38.2	67.0
19	104.4	66.8	37.6	68.6
20	103.6	65.0	38.6	67.6
—	—	—	—	—
21	104.2	65.6	38.6	69.0
22	103.2	65.6	37.6	66.8
—	—	—	—	—
23	103.4	65.0	38.4	65.0
24	101.8	65.0	36.8	66.4
25	101.4	64.2	37.2	65.0
26	101.4	64.4	37.0	64.6
27		Free association test		
28	104.0	65.0	39.0	64.6
29	100.2	64.6	35.6	64.6
30	103.0	65.2	37.8	63.8

TABLE 28

Reactor 5

Averages of blood pressure and heart rate for ten days

READING	SYSTOLIC	DIASTOLIC	PULSE PRESSURE	HEART RATE
1	111.2	61.6	49.6	65.6
2	111.4	61.8	49.6	64.0
3	112.2	62.2	50.0	67.0
4	112.0	62.4	49.6	65.8
5	112.2	61.2	51.0	66.2
6	111.4	61.8	49.6	64.4
7	111.0	61.8	49.2	65.4
8	109.4	61.4	48.0	66.2
9	Free association test			
10	110.8	61.6	49.2	63.0
11	110.8	62.4	48.4	63.2
12	109.2	62.8	46.4	63.6
+	Began smoking			
13	110.2	65.6	44.6	62.0
14	113.4	66.0	47.4	63.2
15	113.6	67.6	46.0	66.2
16	115.0	68.2	46.8	68.6
17	117.0	69.2	47.8	69.2
18	117.4	70.8	46.6	70.4
19	118.2	70.6	47.6	68.8
—	—	—	—	—
20	118.0	71.0	47.0	69.2
21	116.2	70.8	45.4	69.2
22	118.6	72.8	45.8	71.2
—	—	—	—	—
23	117.0	70.8	46.2	70.8
24	114.8	68.0	46.8	70.8
25	116.4	69.0	47.4	67.4
26	115.6	68.4	47.2	67.0
27	Free association test			
28	114.4	69.6	44.8	69.2
29	115.0	66.8	48.2	67.0
30	113.8	66.6	47.2	68.8

TABLE 29

Reactor 6

Averages of blood pressure and heart rate for ten days

READING	SYSTOLIC	DIASTOLIC	PULSE PRESSURE	HEART RATE
1	109.8	64.4	45.4	74.4
2	110.4	64.2	46.2	75.6
3	109.8	64.8	45.0	75.6
4	109.4	63.0	46.4	75.2
5	110.4	65.6	44.8	75.6
6	110.0	64.8	45.2	75.2
7	109.8	64.8	45.0	72.2
8	109.4	64.0	45.4	72.2
9	Free association test			
10	108.0	63.6	44.4	71.0
11	106.8	64.6	42.2	72.4
12	107.8	64.4	43.4	68.4
+	Began smoking			
13	109.2	65.4	43.8	71.8
14	109.0	65.6	43.4	70.0
15	109.8	65.8	44.0	74.8
16	109.8	66.2	43.6	74.0
17	110.0	67.8	42.2	76.4
18	110.0	68.0	42.0	76.2
19	109.8	67.8	42.0	78.8
—	—	—	—	—
20	110.4	68.8	41.6	76.2
21	112.0	68.0	44.0	77.2
22	112.4	68.8	43.6	78.0
23.	111.4	69.0	42.4	76.8
24	111.2	68.8	42.4	78.0
—	—	—	—	—
25	110.6	67.6	43.0	77.8
26	110.2	67.8	42.4	74.4
27	Free association test			
28	110.2	68.0	42.2	73.8
29	108.6	68.6	40.0	76.2
30	108.2	68.4	39.8	73.8

TABLE 30

Reactor 8

Averages of blood pressure and heart rate for ten days

READING	SYSTOLIC	DIASTOLIC	PULSE PRESSURE	HEART RATE
1	96.8	56.6	40.2	67.6
2	97.8	57.4	40.4	67.4
3	98.8	57.6	41.2	66.4
4	99.2	58.4	40.8	66.2
5	100.2	58.6	41.6	67.2
6	100.0	58.4	41.6	67.6
7	98.6	59.0	39.6	66.4
8	99.6	58.6	41.0	68.0
9		Free association test		
10	98.0	58.2	39.8	67.2
11	97.2	58.8	38.4	66.8
12	98.2	59.0	39.2	63.8
+		Began smoking		
13	98.8	59.4	39.4	65.4
14	100.8	59.6	40.2	65.2
15	100.6	59.6	40.0	63.8
16	99.2	60.4	38.8	66.0
17	100.6	61.2	39.4	65 2
18	102.2	61.0	41.2	67.6
19	102.6	60.6	42.0	68.0
—	—	—	—	—
20	100.8	61.0	39.8	65.4
21	102.6	60.4	42.2	63.6
22	103.8	62.0	41.8	64.0
23	100.0	61.0	39.0	64.6
24	103.2	61.8	41.4	65.4
25	102.2	61.2	41.0	64.0
—	—	—	—	—
26	101.8	61.0	40.8	64.0
27		Free association test		
28	98.4	60.2	38.2	67.2
29	99.2	61.6	37.6	63.8
30	99.8	61.0	38.8	65.4

TABLE 31

Reactor 9

Averages of blood pressure and heart rate for ten days

READING	SYSTOLIC	DIASTOLIC	PULSE PRESSURE	HEART RATE
1	107.8	65.2	42.6	73.2
2	108.6	64.4	44.2	71.8
3	107.2	65.4	41.8	72.4
4	106.8	66.0	40.8	73.4
5	106.4	65.4	41.0	71.6
6	106.0	65.2	40.8	73.2
7	105.8	64.6	41.2	71.2
8	104.6	64.6	40.0	69.6
9	Free association test			
10	105.0	65.0	40.0	70.4
11	106.6	66.2	40.4	72.2
12	104.2	65.6	38.6	69.4
+	Began smoking			
13	107.6	66.6	41.0	69.0
14	107.8	68.2	39.6	70.2
15	107.6	67.2	40.4	71.4
16	107.8	67.8	40.0	71.0
17	108.2	68.8	39.4	72.6
18	107.8	69.6	38.2	72.8
19	108.8	69.6	39.2	73.8
20	109.0	70.4	38.6	75.0
—	—	—	—	—
21	109.0	68.2	39.8	74.8
22	108.0	70.8	37.2	74 2
23	108.6	69.2	39.4	74.6
24	106.8	69.2	38.6	74.4
25	108.6	69.6	39.0	76.4
—	—	—	—	—
26	107.8	70.2	37.6	73.6
27	Free association test			
28	106.6	68.2	39.4	72.2
29	106.6	68.4	38.2	70.0
30	107.8	70.4	37.4	73.8

TABLE 32

Reactor 10 (*woman*)

Averages of blood pressure and heart rate for ten days

READING	SYSTOLIC	DIASTOLIC	PULSE PRESSURE	HEART RATE
1	93.8	57.2	36.6	73.2
2	92.0	57.0	35.0	74.2
3	93.2	56.2	37.0	74.6
4	91.8	56.8	35.0	76.6
5	92.8	57.0	35.8	75.8
6	93.2	57.4	35.8	73.4
7	94.2	57.8	36.4	74.6
8	94.0	57.6	36.4	74.4
9	Free association test			
10	91.8	56.6	35.2	70.8
11	93.0	57.2	35.8	72.8
12	92.8	58.0	34.8	71.8
+	Began smoking			
13	95.6	59.4	36.2	74.4
14	94.0	58.4	35.6	73.6
15	95.4	59.4	36.0	73.4
16	96.6	59.4	37.2	73.2
17	96.4	58.8	37.6	76.0
18	96.0	59.6	36.4	76.0
19	97.8	60.4	37.4	75.4
20	98.4	60.4	38.0	75.2
21	96.2	60.2	36.0	74.8
—	—	—	—	—
22	97.0	59.4	37.6	74.8
23	95.2	60.4	34.8	74.8
24	94.4	60.2	34.2	73.4
25	94.4	60.2	34.2	72.0
—	—	—	—	—
26	93.8	60.0	33.8	73.0
27	96.4	60.0	36.4	70.4
28	Free association test			
29	93.0	58.0	35.0	71.0
30	91.8	59.4	32.4	72.4
31	95.2	59.0	36.2	73.0

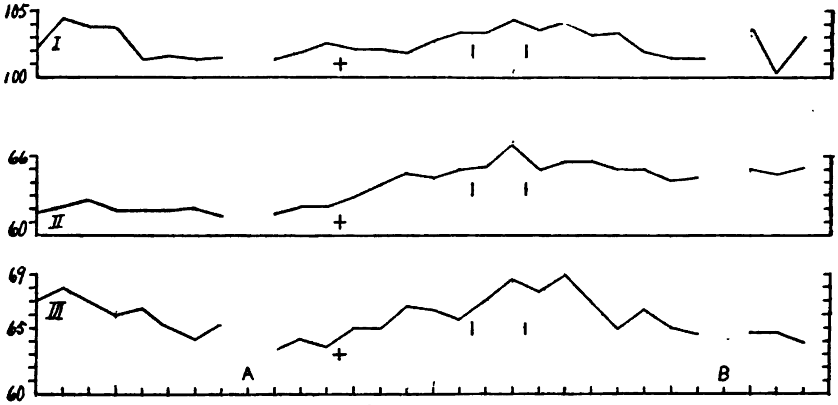


FIG. 10. REACTOR 2

Averages of systolic pressure (I) and diastolic pressure (II) in millimeters of mercury; and of heart rate (III) in beats per minute; for ten days.

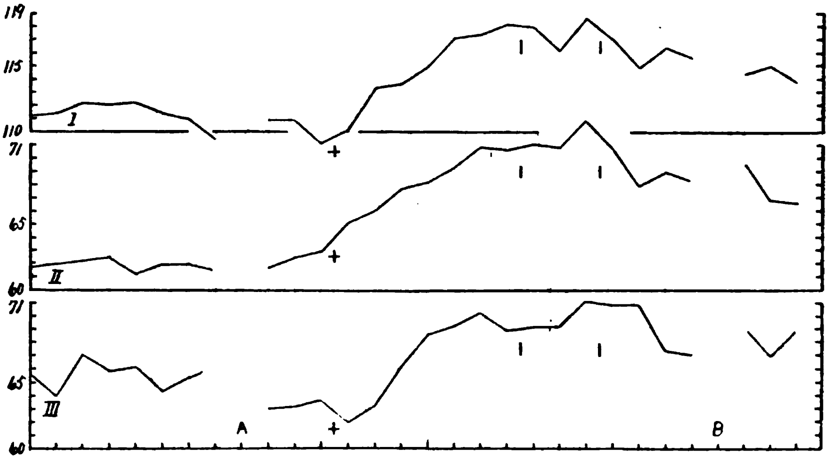


FIG. 11. REACTOR 5

Averages of systolic pressure (I) and diastolic pressure (II) in millimeters of mercury; and of heart rate (III) in beats per minute; for ten days.

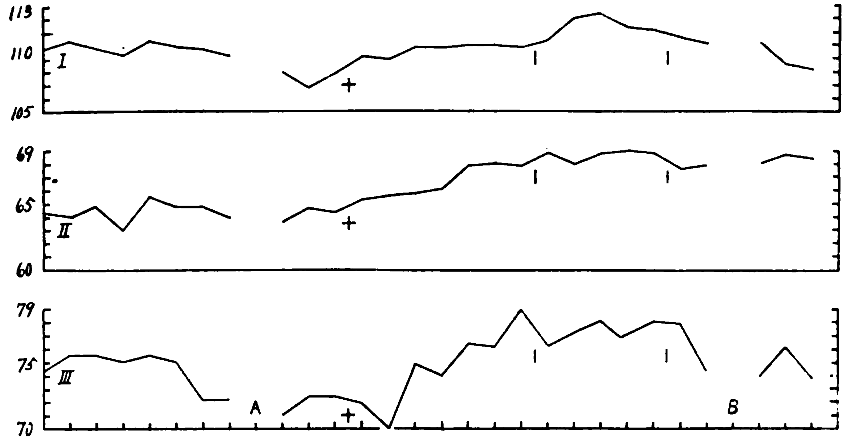


FIG. 12. REACTOR 6

Averages of systolic pressure (I) and diastolic pressure (II) in millimeters of mercury; and of heart rate (III) in beats per minute; for ten days.

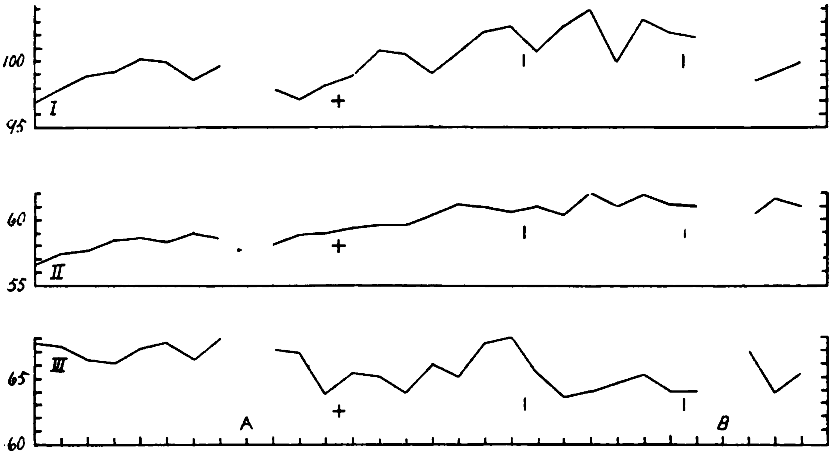


FIG. 13. REACTOR 8

Averages of systolic pressure (I) and diastolic pressure (II) in millimeters of mercury; and of heart rate (III) in beats per minute; for ten days.

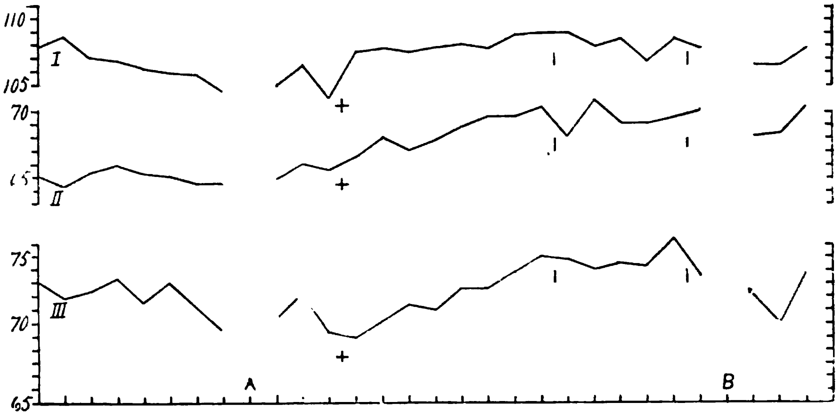


FIG. 14. REACTOR 9

Averages of systolic pressure (I) and diastolic pressure (II) in millimeters of mercury; and of heart rate (III) in beats per minute; for ten days.

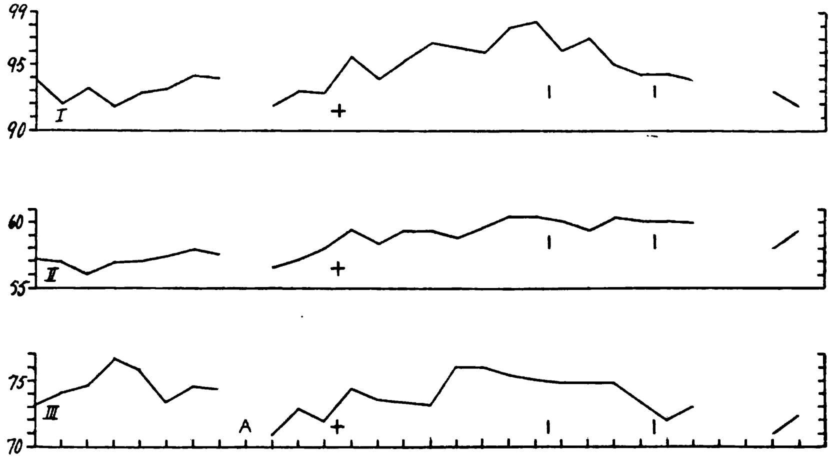


FIG. 15. REACTOR 10

Averages of systolic pressure (I) and diastolic pressure (II) in millimeters of mercury; and of heart rate (III) in beats per minute; for ten days.

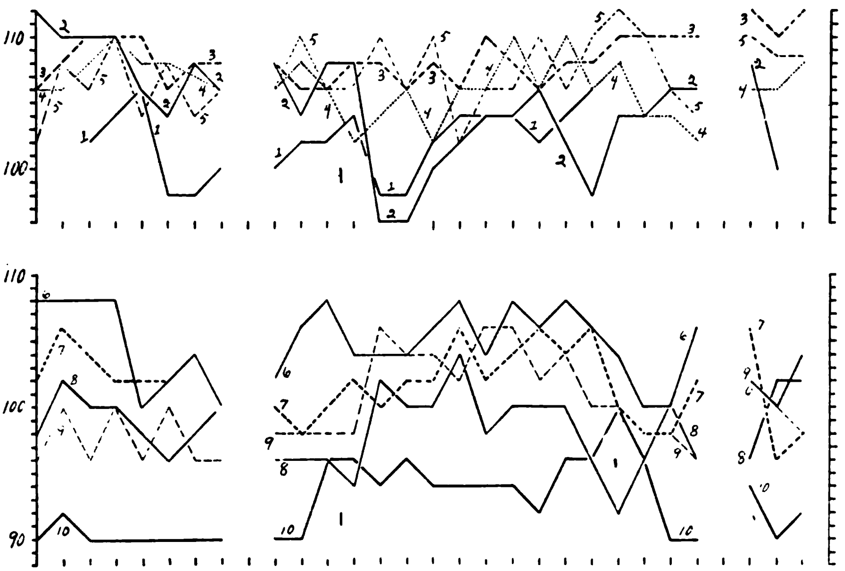


Fig. 16. Reactor 2

Daily readings (not averages) of systolic pressure, in millimeters of mercury. The numbers from 1 to 10 indicate the days.

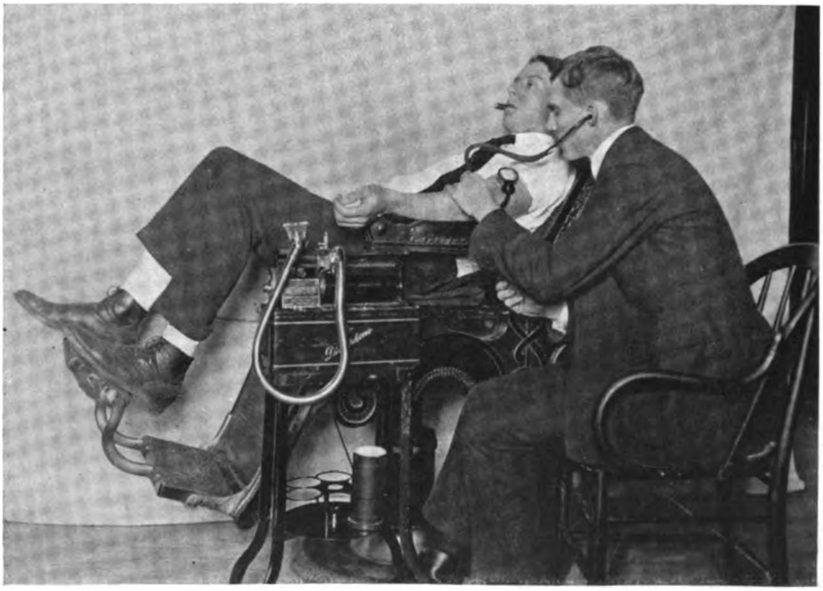


Fig. 17

Position of reactor for blood pressure and heart rate readings

AUTHOR AND SUBJECT INDEX

ANIMAL behavior, A tentative classification of the forms of. S. J. Holmes, 173–186

Animal learning, The nature of unsuccessful acts and their order of elimination in. Zing Yang Kuo, 1–28

Attention, distraction, and fatigue. F. C. Dockeray, 331–370

BATES, ROBERT LEE. The effects of cigar and cigarette smoking on certain psychological and physiological functions. I. Dart throwing, 371–424

BATES, ROBERT LEE. The effects of cigar and cigarette smoking on certain psychological and physiological functions. II. Blood pressure and heart rate, 431–505

Blood pressure and heart rate. (Effects of smoking on.) Robert Lee Bates, 431–505

CARVER, DAVID JUNE. The immediate psychological effects of tobacco smoking, 279–302

Coördination in the starfish. II. Locomotion. W. F. Hamilton, 61–76

Coördination in the starfish. III. The righting reaction as a phase of locomotion, 81–94

DART throwing. (Effects of smoking on.) Robert Lee Bates, 371–424

DOCKERAY, F. C. Attention, distraction and fatigue, 331–370

FATIGUE, Attention, distraction and. F. C. Dockeray, 331–370

Fatigue effects as measured by sugar content of blood. Buford J. Johnson, 155–172

GUINEA pig, A study of the spontaneous activity of the. Edith E. Nicholls, 303–330

HABIT interference in the white rat and in human subjects. Walter S. Hunter, 29–60

Habits, The integrative character of. J. R. Kantor, 195–226

HAMILTON, W. F. Coördination in the starfish. II. Locomotion, 61–76

HAMILTON, W. F. Coördination in the starfish. III. The righting reaction as a phase of locomotion, 81–94

HOLLINGWORTH, H. L. Hurst, Arthur F. *The Psychology of the Special Senses and their Functional Disorders*, 77–80

HOLMES, S. J. A tentative classification of the forms of animal behavior, 173–186

HUNTER, WALTER S. Habit interference in the white rat and in human subjects, 29–60

HUNTER, WALTER S., assisted by ELOISE SOMMERMIER. The relation of degree of Indian blood to score on the Otis intelligence test, 257–278

HURST, ARTHUR F. *The Psychology of the Special Senses and their Functional Disorders*. H. L. Hollingworth, 77–80

INDIAN blood, The relation of degree of: to score on the Otis intelligence test. Walter S. Hunter

assisted by Eloise Sommermier, 257–278
Instinctive locomotor reactions of the loggerhead turtle in relation to its senses, The. G. H. Parker, 425–430
Intelligence test, The relation of degree of Indian blood to score on the Otis. Walter S. Hunter assisted by Eloise Sommermier, 257–278

JOHNSON, BUFORD J. Fatigue effects as measured by sugar content of blood, 155–172

KANTOR, J. R. The integrative character of habits, 195–226
KUO, ZING YANG. The nature of unsuccessful acts and their order of elimination in animal learning, 1–28

LOCOMOTION. (Coördination in the starfish.) W. F. Hamilton, 61–76
Locomotor reactions of the loggerhead turtle in relation to its senses, The instinctive. G. H. Parker, 425–430

McDONALD, HELEN E. Ability of *Pimephales notatus* to form associations with sound vibrations, 191–194
Mudminnows, The ability of: to form associations with sounds. Florence Westerfield, 187–190
Music appreciation, The sensorial basis of. Otto Ortmann, 227–256

NICHOLLS, EDITH E. A study of the spontaneous activity of the guinea pig, 303–330

ORTMANN, OTTO. The sensorial basis of music appreciation, 227–256

PARKER, G. H. The instinctive locomotor reactions of the loggerhead turtle in relation to its senses, 425–430
Pimephales notatus, Ability of: to form associations with sound vibrations. Helen E. McDonald, 191–194
Psychology of the Special Senses and their Functional Disorders, The. Arthur F. Hurst. H. L. Hollingworth, 77–80

RAT, Habit interference in the white: and in human subjects. Walter S. Hunter, 29–60
Rat, The congenital sexual behavior of the young male albino. Calvin P. Stone, 95–154
Righting reaction as a phase of locomotion, The. (Coördination in the starfish.) W. F. Hamilton, 81–94

SEXUAL behavior of the young male albino rat, The congenital. Calvin P. Stone, 95–154
Smoking, The effects of cigar and cigarette: on certain psychological and physiological functions. I. Dart throwing. Robert Lee Bates, 371–424
Smoking, The effects of cigar and cigarette: on certain psychological and physiological functions. II. Blood pressure and heart rate. Robert Lee Bates, 431–505
Smoking, The immediate psychological effects of tobacco. David June Carver, 279–302
Sounds, The ability of mudminnows to form associations with. Florence Westerfield, 187–190
Sound vibrations, Ability of *Pimephales notatus* to form associations with. Helen E. McDonald, 191–194
Spontaneous activity of the guinea pig, A study of the. Edith E. Nicholls, 303–330
Starfish, Coördination in the. II. Locomotion. W. F. Hamilton, 61–76
Starfish, Coördination in the. III. The righting reaction as a phase of locomotion, 81–94

STONE, CALVIN P. The congenital sexual behavior of the young male albino rat, 95–154

Sugar content of blood, Fatigue effects as measured by. Buford J. Johnson, 155–172

TOBACCO smoking, The immediate psychological effects of. David June Carver, 279–302

Turtle, The instinctive locomotor reactions of the loggerhead: in relation to its senses. G. H. Parker, 425–430

UNSUCCESSFUL acts, The nature of: and their order of elimination in animal learning. Zing Yang Kuo, 1–28

WESTERFIELD, FLORENCE. The ability of mudminnows to form associations with sounds, 187–190

The Publication Plan of Psychology Classics

In order to facilitate the preparation of further translations and reprints, the royalties from these volumes will be matched by an equal amount by the Williams & Wilkins Company, the fund so constituted to be deposited with the treasurer of the Johns Hopkins University, and will be applied solely to the defraying of clerical and other necessary expenses of such preparation. The Editor requests suggestions concerning future volumes, and coöperation in their production.

Psychology Classics

The Emotions **Vol. I**

Price, Net, Postpaid

$3.50, United States, Mexico, Cuba
3.75, Canada
4.00, Other Countries

WILLIAMS & WILKINS COMPANY
Publishers of Scientific Journals and Books
BALTIMORE, U. S. A.

The JOURNAL OF COMPARATIVE PSYCHOLOGY will accept for publication, studies which contribute to our knowledge of mental function and behavior in any organism.

Manuscripts may be sent to Knight Dunlap, The Johns Hopkins University, Baltimore, Md.; to Robert M. Yerkes, 1701 Massachusetts Ave., N. W., Washington, D. C.; or to any other member of the editorial board.

Twenty-five reprints of articles will be furnished gratis to contributors when ordered in advance. An order slip, with table of cost of additional reprints, is sent with proof.

The JOURNAL OF COMPARATIVE PSYCHOLOGY is published every other month, appearing February, April, June, August, October and December. At present, one volume of approximately 500 pages is issued a year. Subscription is by the volume only, and not by the year. The *Comparative Psychology Monographs* are issued irregularly.

Correspondence concerning business matters should be addressed to WILLIAMS & WILKINS COMPANY, Publishers of Scientific Journals and Books, Mount Royal and Guilford Avenues, Baltimore, U. S. A.

Subscription Price: Current Volume: Volume II, United States and dependencies, Mexico, Cuba, $5.00; Canada, $5.25; other countries, $5.50. These rates apply also to the *Comparative Psychology Monographs*. Prices are net, postpaid. *Foreign subscriptions to the current volume accepted at par of exchange.*

Back Volume: Vol. I: Price, $6.00, United States, Mexico, Cuba; $6.25, Canada; $6.50, other countries. Prices are net, postpaid.

Back Volumes: Complete sets of *Psychobiology* (Volumes I and II), of the *Journal of Animal Behavior* (Volumes I to VII, inclusive) and of the *Behavior Monographs* (volumes I to IV), may be obtained from the publishers of the *Journal of Comparative Psychology* at the price of $5.00, United States and dependencies, Mexico and Cuba; Canada, $5.25; other countries, $5.50 per volume. Prices are net, postpaid. *Foreign subscriptions to the back volumes accepted at the current rate of exchange.*

Single Volumes, when available, may be obtained at $5.00 a volume. The complete sets are not broken to supply single volumes.

Subscriptions are received at the following addresses:

For Agentina and Uruguay: Beutelspacher & Cia., Sarmiento 815, Buenos Aires, Argentina.

For Australia: Stirling & Co., 317 Collins St., Melbourne; G. Jervis Manton, 430 Little Collins Street, Melbourne (and at Sydney and Brisbane); or Angus & Robertson, 89–95 Castlereagh Street, Sydney.

For Belgium: Henri-Lamertin, 58 Rue Coudenberg, Bruxelles.

For the British Empire, except Australia and Canada: Bailliere, Tindall & Cox; Arthur F. Bird; Wm. Dawson & Sons, Ltd.; Dulau & Co., Ltd.; H. K. Lewis & Co.; David Nutt; J. Poole & Co.; Wheldon & Wesley; Williams & Norgate, London; James Thin, Edinburgh.

For Canada: Wm. Dawson and Sons, Ltd., 87 Queen Street, East, Toronto, Canada.

For Denmark: H. Hagerup's Boghandel, Gothersgade 30, Kovenhavn.

For France: Emile Bougault, 48, Rues des Ecoles, Paris.

For Germany: R. Friedländer & Sohn, Buchhandlung, Carlstrasse, 11, Berlin, NW. 6.

For Holland: Scheltema & Holkema, Rokin 74–76, Amsterdam, Holland.

For Japan and Korea: Maruzen Company, Ltd. (Maruzen-Kabushiki-Kaisha), 11 to 15 Nihonbashi Tori-Sanchome, Tokyo; Fukuoka, Osaka, Kyoto, and Sendai, Japan.

For Spain: Ruiz Hermanos, Plaza de Santa Ana, 13, Madrid.

For the United States and other countries except as above: WILLIAMS & WILKINS COMPANY, MOUNT ROYAL AND GUILFORD AVENUES, BALTIMORE, U. S. A.

No claims for copies lost in the mails will be allowed unless such claims are received within 30 days (90 days, foreign) of the date of issue. Claimants must state that the publication was not delivered at their recorded address. The publishers will not be responsible for loss due to change of address unless notification is received at least one week in advance of issue.

The Journal of Personnel Research

OFFICIAL PUBLICATION OF PERSONNEL RESEARCH FEDERATION

Original researches in the applied sciences that contribute to our knowledge and effective direction of people at work

Editor-in-Chief
LEONARD OUTHWAITE
Personnel Research Federation

Managing Editor
CLARENCE S. YOAKUM
Director Bureau of Personnel Research
Carnegie Institute of Technology

Membership of the Personnel Research Federation

National Research Council
Research Information Service
Engineering Foundation
American Federation of Labor
Bryn Mawr College
Carola Woerishoffer Department of Socia Economy and Social Research
Bureau of Industrial Research
Bureau of Vocational Information
Carnegie Institute of Technology
Bureau of Personnel Research
Dartmouth College
National Committee for Mental Hygiene
University of Pennsylvania
Department of Industrial Research, Wharton School of Finance and Commerce

The journal will be issued monthly and will consist of 600 pages per annual volume. The first issue will appear May, 1922.

Price per volume, net postpaid, $5.00, United States, Mexico, Cuba; $5.25, Canada; $5.50, other countries.

Williams & Wilkins Company
Publishers of Scientific Journals and Books
Baltimore, U. S. A.

AUTHORITATIVE BOOKS

The Determination of Hydrogen Ions (Clark) 2nd ed.	$5.00
The Vitamine Manual (Eddy)	2.50
The Vitamines (Funk) 2nd ed.	5.50
The Heart Rhythms (Lamson)	2.50
Origin and Evolution of the Human Dentition (Gregory)	3.50
Psychology Classics: The Emotions (James-Lange)	3.50
Dictionary of Botanical Equivalents (Artschwager and Smiley)	2.00
Color Chart of Indicators (Clark)	1.00
Carriers in Infectious Diseases (Nichols)	3.00
The Bacteriophage—Its Rôle in Immunity (d'Hérelle). Amer Ed	4.00
Eugenics, Genetics and the Family	6.00
Eugenics in Race and State	6.00
Chemistry of Tuberculosis (Wells)	5.00
The Use of Job Analysis in Curriculum Construction (Strong and Uhrbrock)	In Press
Bacteriology (Conn)	In Press
The Amino Acids (Holm and Gortner)	In Press
Rest and Other Things (Krause)	In Press
Environment and Resistance in Tuberculosis (Krause)	In Press
Tubercle Bacillus Infection and Tuberculosis in Man and Animals (Calmette). Amer. Ed	In Press

Canada, add 25 cents; other countries add 50 cents

WILLIAMS & WILKINS COMPANY
Publishers of Scientific Journals and Books
Baltimore, Maryland, U. S. A.

A NEW JOURNAL

Archives of Occupational Therapy

The Official Organ of the American Occupational Therapy Association

EDITED BY
WILLIAM R. DUNTON, Jr., M.D.
Sheppard and Enoch Pratt Hospital, Towson, Md.

Occupational Therapy has as its object the restoration of the physical or mental functions of men, women and children, by means of carefully planned work, exercise, or amusements.

If you are interested in the hand crafts you will want this periodical.

Price $5.00 the year; issued bi-monthly; 600 pages to the volume.

PUBLISHED BY
WILLIAMS & WILKINS COMPANY
BALTIMORE, U. S. A.

Of interest to Psychologists, Philosophers, Physiologists, and all concerned in mental life

PSYCHOLOGY CLASSICS*

A SERIES OF REPRINTS AND TRANSLATIONS

EDITED BY

KNIGHT DUNLAP
Johns Hopkins University

VOLUME I

THE EMOTIONS

JAMES–LANGE

CONTENTS

PAGE
EDITOR'S PREFACE........ 5
WHAT IS AN EMOTION? *William James*........ 11
THE EMOTIONS, *Carl Georg Lange*........ 33
THE EMOTIONS, *William James*........ 93

The first volume of *Psychology Classics* presents a new translation of Lange's *Ueber Gemüthsbewegungen*, made by Miss Istar A. Haupt from Kurella's German version: together with a reprinting of James' *What is an Emotion?* and his chapter on "The Emotions" from the *Principles of Psychology*.

In the chapter in the *Principles*, James repeated some of the material which h been presented in the *Mind* article. It has however been deemed adv earlier article as well as the chapter. Historical considerati since the chapter is based both on the article and upon to have these two independent foundations still more important reason, in that the *Mind* esentation of the organic theory of the emotio nciples: and in the latter James concedes muc motions in the way of independence of somatic the former.

Th odern psychology are thus made readily accessible to stude ophy, and physiology; and a real need is served.

Clot ped. 6x9. 135 pages

***The Publication Plan of Psychology Classics**

In order to facilitate the preparation of further translations and reprints, the royalties from these volumes will be matched by an equal amount by the Williams & Wilkins Company, the fund so constituted to be deposited with the treasurer of the Johns Hopkins University, and will be applied solely to the defraying of clerical and other necessary expenses of such preparation. The Editor requests suggestions concerning future volumes, and coöperation in their production.

ORDER FORM

WILLIAMS & WILKINS COMPANY
Publishers of Scientific Journals and Books
Baltimore, Maryland, U. S. A.

Gentlemen:
I enclose $3.50 for one copy of

THE EMOTIONS

SIGNED........

E-4-22-3M

ADDRESS........

Sent on Ten Days' Approval to retail purchasers in the United States and Canada, if desired. Foreign orders must be accompanied by remittance, which will be returned if the book is not kept.

New Periodicals

MEDICINE. Edited by David L. Edsall, Harvard Medical School, and John Howland, Johns Hopkins Medical School; Associate Editor, Paul D. White, Massachusetts General Hospital. Published quarterly. 500 pages to the volume. Established 1922.

Publishes analytical reviews of general medicine, neurology and pediatrics.

JOURNAL OF COMPARATIVE PSYCHOLOGY. Edited by Knight Dunlap, Johns Hopkins University, and Robert M. Yerkes, National Research Council. Published bimonthly. 500 pages to a volume. Established 1921.

Publishes studies contributing to the knowledge of mental function and behavior in any organism.

COMPARATIVE PSYCHOLOGY MONOGRAPHS. Edited by Walter S. Hunter, University of Kansas, in association with an editorial board. Published irregularly. 500 pages to a volume. Established 1922.

The Monographs will publish studies contributing to the knowledge of mental function and behavior in any organism.

JOURNAL OF PERSONNEL RESEARCH. Edited by Leonard Outhwaite, Personnel Research Federation, in association with an editorial Board. Published monthly. 600 pages to a volume. Established 1922.

Publishes researches in the various sciences that contribute to our knowledge and effective direction of people at work.

ARCHIVES OF OCCUPATIONAL THERAPY. Edited by Wm. R. Dunton, Jr., Sheppard and Enoch Pratt Hospital, in connection with an editorial board. Published bimonthly. 500 pages to a volume. Established 1922.

Devoted to the publishing of fundamental data on occupational therapy in its relation to medicine, surgery, sociology, and handicrafts.

Price per volume, net, postpaid, $5.00, United States, Mexico, Cuba; $5.25, Canada; $5.50, other countries.

WILLIAMS & WILKINS COMPANY
Publishers of Scientific Journals and Books
BALTIMORE, U. S. A.

CONTENTS

Robert Lee Bates. The effects of cigar and cigarette smoking on certain psychological and physiological functions........ 431